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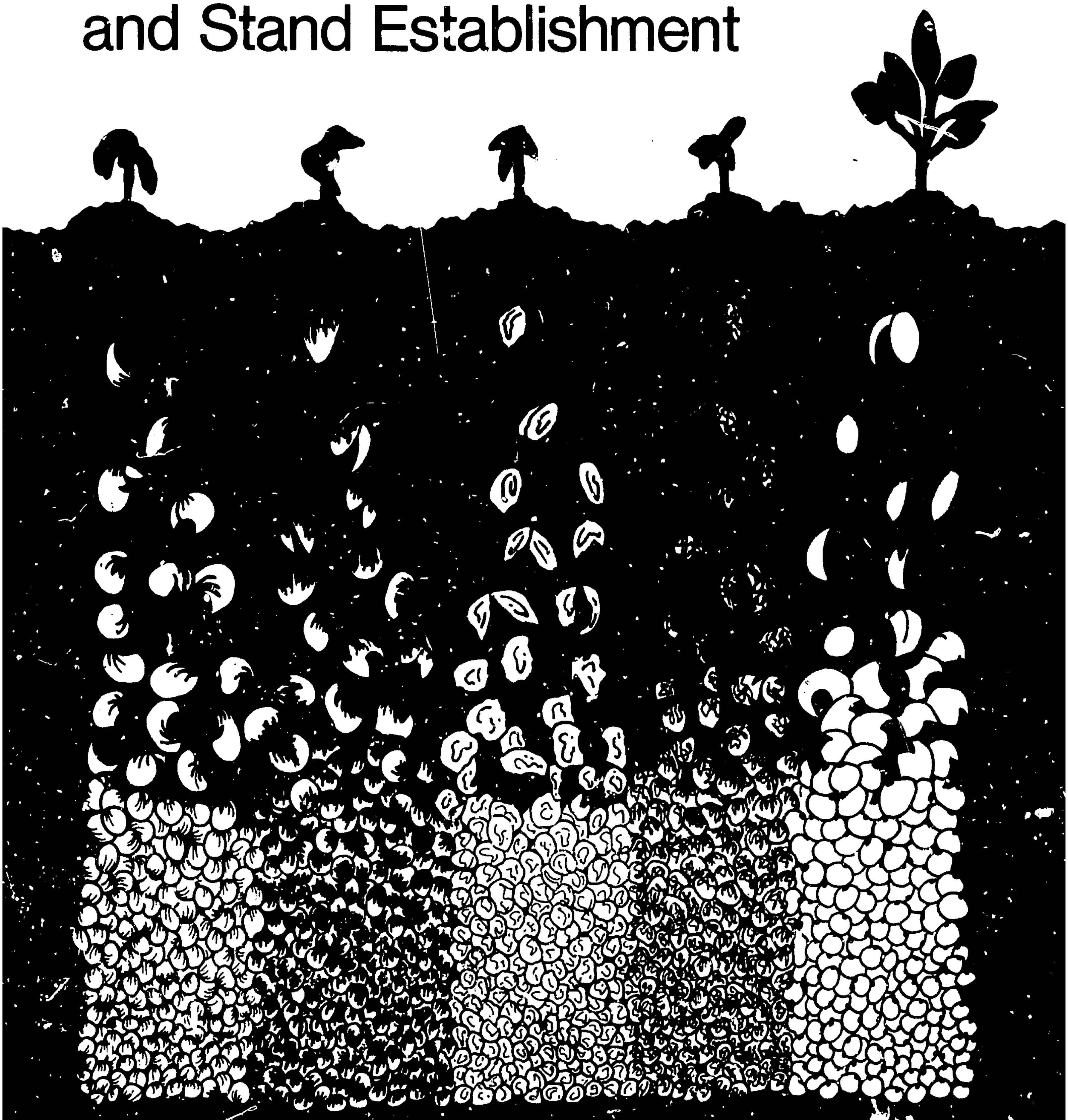

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COLLEGE OF AGRICULTURE UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Soybean Seed Quality and Stand Establishment

Proceedings of a Conference for Scientists of Asia

January 25-31, 1981
Colombo, Sri Lanka
Edited by J.B. Sinclair and J.A. Jackobs

INTSOY

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COLLEGE OF AGRICULTURE / UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

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Foreword

The Conference on Soybean Seed Quality and Stand Establishment, sponsored by the Sri Lanka Ministry of Agricultural Development and Research, the Seed Technology Laboratory at Mississippi State University, and the International Soybean Program (INTSOY) at the University of Illinois at Urbana-Champaign, in collaboration with the United Nations Food and Agriculture Organization, Rome, and the United States Agency for International Development (USAID), Washington, D.C., was held at the Agrarian Research and Training Institute, in Colombo, Sri Lanka, January 25 to 31, 1981.

The committee responsible for planning the Colombo conference set forth four major objectives:

1. To identify the current state of knowledge about the factors that affect soybean seed quality and stand establishment in tropical and subtropical environments;
2. To determine appropriate means of disseminating this information to soybean farmers and seed producers;
3. To define additional research needs in order to remove constraints and increase production of high quality soybean seed; and
4. To establish a priority agenda for research on the harvesting, handling, storage, distribution, and sowing of soybean seed leading to the improvement of viability and field germination.

Part of the rationale for the conference came from the experience in the INTSOY variety trials program, particularly the International Soybean Variety Evaluation Experiment (ISVEX), which indicated that high quality soybean seeds can be produced in tropical and subtropical environments. However, impressive experimental results have not been translated satisfactorily into small farmer experience. Stand establishment is often quoted as a general problem in most developing countries where soybeans are being grown. While some farmers in the humid tropics have enjoyed success in soybean production, the establishment of an adequate stand of vigorous soybean seedlings remains a major limiting factor. The number and vigor of seedlings that become established and grow to maturity affect the quanity and quality of the seed crop.

Current research has shown that both physical and biological factors are responsible for reduced seed quality and poor seedling vigor. Successful stand establishment is dependent upon the quality of the planting seed, and seed quality is directly influenced by weather conditions during seed maturation and harvest and by subsequent storage conditions. The problem is particularly severe when planting seed is saved from locally grown plants. At previous INTSOY conferences and workshops, questions on seed quality and stand establishment have frequently been asked, and discussions have shown that this is a major area of concern to the participants. This concern suggests that the existing knowledge about the factors affecting soybean seed quality and stand establishment is fragmented and is not being effectively communicated to farmers.

The relevance of this conference to current and future soybean development activities is that all the information presented is related directly to (1) seed production, (2) seed technology and storage, and (3) seed certification in developing countries of the tropics and subtropics. It is especially relevant to present production problems in countries where high ambient temperatures and humidity prevail at harvest and during storage, and where high soil temperature and moisture prevail at planting time.

The objectives of this conference relate directly to the overall INTSOY goals of gathering, distilling, and disseminating the best current knowledge of problems facing small farmers. It includes objectives designed to remove constraints of cultivar and crop husbandry techniques and to develop improved systems for both production and harvesting of seed. The objectives of the conference also relate to complementary programs of international donor agencies, for example, the FAO Regional Field Food Crops project, which has been active in North Africa and the Middle East for several years in promoting food crop production through applied research and demonstration programs.

The conference brought together extension workers and research scientists to upgrade knowledge and improve communications. Results of the conference are of significant importance to INTSOY, as it works to develop a network of cooperators for cultivar and crop husbandry research and to enable cooperating countries to develop sources and distribution systems of high quality planting seed.

The proposal for the conference was approved by the INTSOY Executive Committee. During a visit to the University of Illinois at Urbana-Champaign, the Honorable E.L. Senanayake, Minister of Agricultural Development and Research, Republic of Sri Lanka, expressed the willingness of the Sri Lankan government to cosponsor the conference. In addition, the internationally respected Seed Technology Laboratory, Mississippi State University, agreed to be a cosponsor and to assist in the planning and conducting of the conference.

A planning committee was named in September 1979 to develop the program outline and suggest speakers. It was composed of representatives of INTSOY staff members from the University of Puerto Rico and the University of Illinois at Urbana-Champaign, from the Seed Technology Laboratory at Mississippi State University, and from the government of Sri Lanka. The members of the committee canvassed colleagues and institutions both domestic and international for suggestions for highly qualified speakers.

The program was divided into four major sections all relating to soybean planting, seed quality, and stand establishment. The major areas of concentration included factors affecting (1) planting seed at harvest, (2) planting seed in storage, (3) the sowing of planting seed, and (4) stand establishment.

In the plenary session the speakers highlighted the importance of seed quality in the expansion of soybean production in the tropics and subtropics. The Honorable E.L. Senanayake, Minister of Agricultural Development and Research, remarked that as an agriculturist he recognized that an important priority is good seed, without which soybeans can never be an economical crop. The Secretary, Ministry of Agricultural Development, R. Wijeratne, emphasized the important contributions soybeans can make in supplying protein and energy into the human diet. The Director, C.R. Panabokke, Department of Agriculture, Ministry of Agriculture, pointed out that the problems encountered in soybean seed production in the tropics and subtropics are more complex than those of the temperate zone because of the high humidity and high temperatures that prevail throughout the year. He did point out, however, that studies in Sri Lanka have shown that cultivars differ widely in their ability to survive these conditions.

There were registrants representing countries from Africa, Europe, the Far East, North, South, and Central America, and the Caribbean. The invited speakers and delegates as well as those who presented volunteer papers spoke to the general objectives of the conference. Conference facilities and attendance at the formal sessions and on the field trip that followed were excellent. It was clear that obtaining and maintaining high quality planting seed was a major concern of the delegates and was felt to be a restraint on soybean production in the tropics and subtropics. A number of proposals were made in the plenary session.

The conference participants and those who find these Proceedings of value owe their appreciation to many, including the Ministry of Agricultural Development and Research, Sri Lanka; the Department of Agriculture, Sri Lanka; the FAO, Rome, and USAID, Washington, D.C., upon whose financial support the conference depended greatly.

The conference wishes to thank representatives of the following firms who provided services for the conference: Agriculture Research and Training Institute, Hatton National Bank, and Pan American World Airways. Also, sincere appreciation is given to Mrs. A.C. Caldera and her staff, who so efficiently conducted the registration and operated the service desk throughout the conference.

We wish to express our thanks and appreciation to those members of the faculty, staff and nonacademic staff of INTSOY, who contributed in many ways to the planning and preparation of materials for the conference and for the Proceedings.

The government of Sri Lanka; FAO, Rome; USAID, Washington, D.C.; Mississippi State University Seed Technology Laboratory; and INTSOY 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.

W.N. THOMPSON

Director
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Contents

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Inaugural Addresses

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Soybeans as Food through the Ages

E.L. SENANAYAKE

Professor Thompson, Dr. Al-Jibouri, distinguished delegates, ladies and gentlemen, it is my very happy privilege this Monday to stand once again at this rostrum to welcome to our country the distinguished scientists from 30 countries in a very important field of work.

Ladies and gentlemen, it is said that an accident that happened to a Chinese emperor 5,000 years ago was responsible for the discovery of the world's most popular beverage, tea. It is recorded in Chinese history that in about 2800 B.C. a Chinese emperor who was participating in a boar hunt lost his way with only two other companions. The Emperor's retinue had taken another road to keep pace with them. The Emperor was feeling very thirsty, and he wanted his ministers to give him a glass of water. The ministers told the Emperor that the water was not very clean, and they would have to boil it. Even then they knew that the purity of water was very important. So his two companions boiled some water in a pot with some branches cut from a nearby tree. When the Emperor took it to a glass he found that the water was colored. Suspecting that it might be poisoned, he got his two companions to drink it first. That ancient custom, ladies and gentlemen, is prevalent even today in the East, and I know that the French custom of the host's tasting the wine before it is given to the guest is prevalent in the West. The Emperor, upon tasting this, found a distinctive flavor, and when he looked into it he saw some leaves from the branches in the water. That, they say, was the discovery of tea.

We also owe to the Chinese the subject of discussion today. The soybean, they say, is as old as the 5,000-year-old Chinese civilization. Our project coordinator in Sri Lanka, Dr. Herath, told me this morning that that fact may be one of the reasons Chinese civilization has lasted for 5,000 years. Although they were short, small men, they had plenty of protein in them. Coming to the subject, last Monday I had the privilege of welcoming to the Second International Seminar on Winged Bean distinguished scientists who are still in our country. Some of those who attended that seminar, I understand, are present today.

Ladies and gentlemen, toward the end of the 18th century an economist by the name of Malthus was called the Prophet of Doom because he wrote in articles and books that the world population would soon outstrip the world's supply of food. Two centuries later, the FAO and the UNDP, all these bodies that are interested in the production of food, are all prophesying a shortage in grain. This is a very serious matter for the world to consider. It is true that my country goes back 2,523 years and has not suffered a great deal from famine. But in the recent past, in 1973, '74, and '75, there was an unprecedented drought, and I saw people eating things that normally the people of our country do not eat.

The soybean, which is called a miracle bean, is fairly new to us. Prior to the Second World War, the late Mr. Walter Moragoda, Chief Propaganda Officer in the Agriculture Department, encouraged the growing of soybeans. But the crop was adopted only in the village home gardens. We owe a great debt of gratitude to the late Mr. Bill Golden, who, with his untiring efforts, interested the Agriculture Department and the people of Sri Lanka in the soybean. His efforts got us into INTSOY, which has benefited us greatly. Since 1975, through UNDP and FAO assistance, we have had the assistance of Dr. Carl Hittle and his team, who have developed soybeans to a great extent in this country.

We must thank UNICEF and CARE for having sponsored the pilot factory at Gannoruwa, which I hope you will visit during your sojourn here. The factory has encouraged the private sector to come into soybean production, and I am happy to state that my Ministry, with the assistance of the well-known firm,

The Honorable E.L. Senanayake is Minister, Ministry of Agricultural Development and Research, Government of Sri Lanka.

Forbes & Walker, has now entered the soybean industry in a commercial way.

I have seen the sophisticated soybean industry, thanks to the invitation of INTSOY. I spent a week in Illinois, where I learned more about soybeans than if I had read 30 or 40 books. In America the soybean industry is a very, very large industry. I am afraid it will outstrip wheat very soon. I have seen different uses to which soybeans can be put. We in the East have been used to rice; we are a rice-eating people. The westerners are wheat-eating people. But soybeans may some day outstrip both of these when the people of our country come to know the benefits of eating soybeans.

I am happy to see Mrs. Y.Y. Kim here in this hall. She, in her own silent way, has been propagating the use of soybeans at the village level. As I know by experience, the processing of soybeans is a very intricate system, but Mrs. Kim has taught housewives to use the ordinary grinding stone to reduce soybean seed to a powder that is edible. Ladies and gentlemen, the supply of milk in our country is still not meeting our requirements. I think CARE, by introducing Thriposha, has introduced an infant milk food that I hope will catch on in the future and not only stop the drain of our foreign exchange in importing infant milk foods but also give our children a wholesome protein diet.

Fresh discussions on the improvement of seed will take place at this conference. As an agriculturalist, I think the most important priority is good seed, without which you can never expect an economical crop. I am proud to say that our Director of Agriculture, Dr. Panabokke, and his team of research workers have brought Ceylon into the limelight through rice production. His Bathalogoda cultivar has come in first in the International Rice Trials, producing 166 bushels of paddy per acre. He has also created another first, since acreage yield is 59 bushels while the world average is 52.

Therefore, I am sure Dr. Panabokke and his team will promote and improve the cultivation of soybeans in Sri Lanka. In 1975, ladies and gentlemen, we had only 200 acres. We have brought that up to 5,000 acres. My Ministry has guaranteed a floor price so that the middleman will not exploit the sweat and labor of the poor farmers.

Of course, you understand that it will take some time for the people to get used to soybeans as a daily food. We are experimenting with the possibility of using 10 percent soybean flour in baking our bread, which will save a tremendous amount of money spent in foreign exchange. Soya milk for infants is also being promoted by the new Soy Foods Research Centre (SFRC). And the products of the pilot factory have proved to our people that the soybean is definitely a miracle bean. I, therefore, in conclusion, wish to welcome all of you to this conference, and I am sure that the results of your deliberation will be of great use to humanity. Thank you.

Opportune Moment

RANJAN WIJERATNE

I am singularly honored to associate myself with the International Conference on Soybean Seed Quality and Stand Establishment commencing today. Sri Lanka has been fortunate to host this meeting of scientists from nearly 35 countries in the wake of another seminar on a similar crop. There is no moment so opportune as now to plan strategies for the coming decade, when food will be in short supply in the less developed countries. The agricultural sphere in Sri Lanka has been hitherto dominated by high priority programs on cereal food and staples. Agricultural scientists in the country are now being directed to muster their forces to increase the production of grain legumes.

The most successful crop under rainfed conditions on the dry zone highland appears to be the soybean. Quality seed production is, in my opinion, the vital prerequisite to successful farming. During the past three years, the entire seed production program has been revamped to cater to the new development strategy of the government. This conference on seed quality will therefore be not only timely but also beneficial to all agencies and institutions with interest in agricultural development.

Ranjan Wijeratne is Secretary, Ministry of Agricultural Development and Research, Sri Lanka.

Keynote Address: Soybeans in Sri Lanka

C.R. PANABOKKE

Honorable Minister for Agriculture Development and Research, delegates to the Establishment, special representatives from the sponsoring and collaborating agencies, Mr. Secretary, guests, ladies and gentlemen.

It is most fitting that a soybean conference such as this is being held in a tropical country like Sri Lanka. Although soybeans are considered a very old crop in China, going back to before 2500 B.C., this crop did not spread to the other parts of the world until early in the 19th century. The real expansion and development of this crop came after 1942 in response to a wartime shortage of edible fats and oils. In recent years, many of the tropical countries have more than adequately demonstrated a high production potential for soybeans.

The International Soybean Variety Evaluation Experiment (ISVEX) sponsored by the International Soybean Program (INTSOY) gave the first impetus to popularizing this crop. Sri Lanka became an active participant in this program in 1973, and it provided the highest number of testing locations in this country's highly diversified agro-ecological regions. Sri Lanka now has become one of the best locations for testing soybean cultivars in the humid tropics. The results of these tests have been periodically published by INTSOY, and we are proud to announce that some of the highest yields for the ISVEX cultivars have been recorded in Sri Lanka.

This conference deals with the relatively restricted topic of soybean seed quality, which is a very important factor in the whole complex of soybean production. However, in our deliberations we must not lose sight of all the components that are necessary for the successful development of a soybean industry. These include production, marketing, processing, and utilization. If a new soybean industry is to develop within a reasonable period of time in any country, there should be an appropriate balance of emphasis on all these components, since while the industry is being developed there will be a host of new problems—technical, social economic and cultural.

One of the basic and first needs is quality planting material. This, in my opinion, is a vital input because both initial crop establishment and performance are mainly dependent on this. Good seed is fundamental to success in any kind of agriculture. Soil scientists will identify areas of soil that have high potential; agronomists will endeavor to provide the best soil and cultural conditions to receive the seed; physiologists will try to synchronize with the best environmental conditions and timely seeding to obtain the maximum benefits. In all these situations that I have mentioned, there is one common factor that is of interest to the farmer, namely, profit.

I have seen fields of soybeans which, as the Honorable Minister pointed out, could be examples for others. The dry zone farmer now is clearly beginning to use soybeans as a Maha crop for settled rain-fed farming in place of Chena or shifting agriculture that he has carried out for centuries. This I consider a very significant development in dry zone agriculture, which has undoubtedly been catalyzed by the unique characteristics of the soybean crop. Soybeans, we find, are very amenable to the dry zone highland where the farmer uses minimum tillage techniques.

We should not be complacent, however, based on a few successes. Technical problems such as breeding cultivars for specific environments, improving seed quality, and improving methods of harvesting, handling, and storage will have to be resolved; and it is the purpose of this conference to help solve these. But human problems are a bit more difficult. A whole new dimension of problems will be encountered when attempts are made to involve people whose social and economic preferences must be considered.

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These are the problems encountered when soy foods are introduced into a society. However, we can safely assume that people will adopt new foods if they are available, if they taste good, and if the price is right. We are aware that apart from traditional foods like meat and fish, which are mainly within the reach of the affluent, the less fortunate have to depend on vegetable proteins for their sustenance. I am proud to say that Sri Lanka is striving very hard to develop processing facilities so that soy foods will be cheap and readily available to a major part of our population.

With regard to the economics and marketing of soybeans, one has to be quite pragmatic. The market must provide a price that is profitable for the producer, the processor, and the retailer, and one that is equally attractive to the consumer as well. A good trade is one in which both parties recognize that they have gotten a good bargain. If we can have a marketing system that will deliver a good product at a price that the consumer considers reasonable, then the market will be there.

Now, let me turn to the central thrust of this conference, namely, soybean seed quality and stand establishment. In the developing countries, it is recognized that the problems encountered in soybean seed production are generally more complex than those of the temperate zone, because of the difficult climatic conditions in the tropical zones. The soybean farmer soon realizes that the soybean seed is entirely different in its behavior from the kind of seeds that he is normally accustomed to, such as paddy, maize, traditional millets such as Kurakkan, and the traditional pulses. Soybeans lose their viability very quickly when stored under conditions of high humidity and high temperature.

Most of you are aware, no doubt, of the climatic and soil regimes that exist in this part of the tropical world. High atmospheric humidity throughout the year predisposes soybean seed to poor viability. In most of the large-seeded cultivars this characteristic is visible. In our earlier investigations we observed that most of the introduced cultivars had brittle and thin seed coats. This resulted in cracks during threshing, harvesting, and handling. Storability was poor and viability went down rapidly. On the other hand, in the small-seeded types, it was found that the seed quality was better.

An old, established cultivar that had been growing in the high elevations of Sri Lanka proved to be a cultivar that stored well, even under high humidity conditions, for as long as 9 months while maintaining a germination of over 90 percent. In a seed storage test conducted with 10 cultivars of both American and Asian origins, it was observed that most of the Asian cultivars were more tolerant to high humidity and normal storage at room temperature. At the end of 12 months, three Asian cultivars, viz. TK 5, TE 32 and PB 1, recorded 70 percent germination, and the Nuwara Eliya local, which was a check treatment, recorded over 90 percent germination. This observation demonstrates that seed quality is an important component in developing a soybean program for the tropics. I have mentioned this study as an example, and I am sure that many of you gathered here will contribute more knowledge to this field as specialists in this subject.

Linked closely with seed viability is the question of seed germination and crop establishment. The farmer in the tropics constantly battles the weather and other elements all the time. Despite the so-called "abundant sunshine" from which he benefits, it should be recognized that he has to battle against difficult problems connected with variable rainfall, poor soil moisture storage, and high soil temperatures at time of planting. We therefore have to build into his farming system some safety devices by which he can safely establish and mature his crop. Seed viability is one, and early seeding vigor is another.

To elaborate further on the foregoing problems in respect to the tropical regions, the following environmental constraints need to be emphasized:

1. High soil temperature at planting time can lower germination and consequently lower seedling vigor. There are times when the soil temperature exceeds 43°C. This hinders germination of the seed, as well as killing the *Rhizobium*; we have to either breed hardier types or change our system of cultivation.
2. Torrential rains immediately after sowing a crop can be detrimental, if followed by dry weather. Soil "capping" or "crusting" occurs and seedling emergence is affected adversely.
3. Soilborne diseases also can affect seedlings. These problems have to be solved by the soybean pathologists.

Sri Lanka is more fortunate than many other tropical countries because it can produce at least two soybean crops per year. One crop is produced as a rain-fed crop during the wet Maha season. The other crop is produced with supplementary irrigation during the dry Yala season. Thus, soybean seeds that are harvested from the Maha crop in January/February can be conveniently used as seeds for the Yala planting in April/May.

Seeds from the Yala crop normally harvested in July/August can be used for the Maha planting in October/November. The period of seed storage, therefore, will be lower than the normal 6 to 8 months that would be needed in the unimodal rainfall types in most of monsoon Asia.

The main strategies in the Sri Lankan program are, therefore, directed along the following lines:

1. Breeding of heat-tolerant types;
2. Breeding and selection for firmness of seed coat;
3. Developing small-seeded cultivars because small size appears to be related to seed viability and because small seeds can emerge more easily from a hard soil surface;
4. Breeding for high seedling vigor to establish early soil cover and minimize erosion; and
5. Adapting double cropping to avoid long storage periods. In Sri Lanka we have achieved this to a great extent in the soybean growing areas that you will visit where farmers store seed by growing a second crop under supplementary irrigation.

Weather conditions not only dictate the type of seed storage but also have an influence on seed quality as the crop matures. We know that unfavorable weather conditions during maturation and harvesting can affect adversely the quality of the seed crop because of pathological and physiological problems resulting from a delay in harvest. In Sri Lanka we match the age duration of different cultivars to the respective rainfall probability regions with a view to minimizing the adverse weather conditions at harvest time. This is of special significance where soybeans are being grown as a rain-fed crop during the Maha season. It is known further that improper methods of harvesting, threshing, and storage usually result in poor seed viability because of mechanical damage. It may be necessary to identify areas in each country where high quality seed can be produced because of more favorable weather conditions. In turn the seed produced there could be distributed throughout the production areas.

Thus, we can see that there are several problems associated with soybean seeds used for planting. The pessimist may think that perhaps the problems are insurmountable. The main purpose of this conference is to discuss these problems, to review the research that has provided at least some solutions to them, and to plan strategies for future research and extension programs. Because the soybean is such a remarkable source of both food and feed, all efforts to improve seed quality will pay off handsomely.

We are pleased to note that participants to this conference come from at least 25 different countries. In addition to the sponsors and collaborators, the participants include soybean research and extension specialists and members of seed industries in the private and public sectors. It is especially gratifying to note that the private sector is included, since in many parts of the world the private sector has a crucial role to play not only in the processing and utilization of the product but, also, in the production and distribution of high quality seeds.

Each of us comes willing to share our knowledge and in search of answers to problems concerning soybean seed quality. We recognize the importance of soybeans in the developing countries, and I believe that you are all willing to work hard during the next 5 days towards the objectives of this conference on seed quality and stand establishment.

Before closing this inaugural session, it seems appropriate to remind ourselves of the objectives of the conference, namely:

1. To identify the current state of knowledge about factors that affect soybean seed quality and stand establishment in tropical and subtropical environments;
2. To determine appropriate means of disseminating this information to soybean farmers and seed production programs;
3. To define additional research needs to remove constraints to increased production of high quality soybean seeds.
4. To establish a priority agenda for research on the harvesting, handling, storage, distribution, and sowing of soybean seeds leading to the improvement of viability and field germination of soybean seeds.

We warmly welcome you to Sri Lanka and wish you all success in your search for ways to improve the quality of soybean seed used for planting material.

Invited Papers

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Soybean Seed Maturation at Different Levels in the Plant Canopy and Viability of Seed Harvested at Different Stages

C.D. DHARMASENA

Reproductive development in indeterminate soybeans (*Glycine max* (L.) Merr.) is initiated at the lower nodes and continues progressively upwards. Although flowering and podding occur over time, harvesting maturity occurs about the same time. This suggests that seeds on the upper part of the plant develop faster than seeds on the lower part.

This investigation seeks answers to the following questions:

1. Is there a difference in dry matter accumulations in seeds at different levels within the plant canopy in indeterminate types?
2. If there is a variation in seed weight within the plant canopy, how would the proportion of different seed sizes change during the developmental period?
3. What variation in germinability would exist among the different seed size classes at different harvest dates?

LITERATURE REVIEW

Reproductive development in the soybean plant is initiated with the axillary buds developing into flowers. Describing the plant habit, Carlson (3) explained that, in indeterminate types, the terminal bud continues vegetative activity during most of the growing season. In indeterminate cultivars, seed and pod development is a continuous process. Fehr et al. (10, 11) developed a convenient system of classifying the growth and reproductive stages.

It was noted by Delouche (5) that seed dry weight increases slowly up to 20 to 30 days after flowering, reaches a maximum at 65 to 75 days after flowering, and remains constant or decreases slightly thereafter. Egli (8) measured dry matter accumulation rates in four soybean cultivars and found that pods reach their maximum weight when seeds have reached 15 to 30 percent of their final weight.

Changes in moisture levels in seeds during development and maturation also are important. Delouche (5) observed that at maximum dry weight, seeds contain 40 to 50 percent moisture, while Mondragon and Potts (18) stated a value of 30 percent. About one week after physiological maturity, seed moisture dropped to about 15 percent (5).

Measurements made by Willard (25) indicated that seed weight was equivalent to 40 percent of the final mature dry weight of the plant. Rates of accumulation of dry matter measured in different plant components by Hanway and Weber (15) showed that seed weight at maturity was 29 percent of the total plant dry matter (including abscised leaves and petioles). In Nigeria, Wien and Ackah (24), working with cowpeas, found that yield was proportional to the length of the reproductive period and that the pod development period was directly related to seed weight. Robitaille (21) tested three indeterminate cultivars of *Phaseolus vulgaris* and observed that cultivars exhibiting continued vegetative growth during the reproductive phase showed the same dry matter accumulation rates as the cultivar that had little vegetative growth during reproduction.

Once physiological maturity is reached, seed moisture drops. Several workers (4, 5, 18) suggested that maturing seed may show considerable variation in moisture level in relation to external moisture regimes. Rainfall and high humidity caused a considerable increase in seed moisture content. Potts et al. (20) found that hard-seeded cultivars are less subject to moisture reabsorption. Seed moisture content was found by Howell et al. (17) to be the primary factor related to respiration rates of seeds rather than temperature.

Egli and Leggett (9) varied source-sink ratios in soybeans by leaf and pod removal and found that seed growth rate depended on long-term photosynthesis, and not as much on photosynthetic activity during the actual pod-filling stage. Egli (8) observed that final yield may remain the same under different

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planting dates due to changes in dry matter accumulation rates.

Working with cowpeas, Wien and Ackah (24) demonstrated that seed weight increased with early planting due to the longer pod development period. However, early planting does not necessarily result in higher yields, as demonstrated by Egli (8).

In soybeans, physiological maturity denotes a stage when seeds have accumulated maximum dry matter (5). Delouche observed that germinability and vigor are highest at physiological maturity although seeds germinate when one-third the maximum dry weight has been accumulated. Willard (25) reported that soybean seed weight increases as long as functioning leaves are present. Subsequently, translocation of assimilates from leaves to seed slows and stops, thus halting seed weight increase. Fehr et al. (12) suggested that physiological maturity is attained at the R_7 stage. However, in a later experiment, they observed that yield reduction is due to defoliation at the R_7 stage. Thus, physiological maturity may be reached close to the R_7 stage.

A wide range of sizes exists within a given seed lot of any particular soybean cultivar. Whether this affects field performance becomes an important question. Burris et al. (2) separated seeds from four cultivars into four size classes and discovered that large seeds had larger embroyos, which exhibited higher respiration rates. However, the rate of loss of cotyledonary nutrients was the same in all size classes.

Singh et al. (22) and Smith and Camper (23) found that seed size had no effect on germination or initial plant stand. They and others (1, 2) observed that larger seeds gave rise to taller plants. Fontes and Ohlrogge (13) and Smith and Camper (23) observed that larger seeds gave rise to higher yielding plants. Comparing different cultivars having different seed sizes, Hartwig and Edwards (16) found that seed size did not influence yield. However, Edwards and Hartwig (7) observed that small and medium-seeded near isogenic lines showed quicker emergence and greater root development than large-seeded lines, which was confirmed by Green et al. (14). Edje and Burris (6) observed that seed vigor was not related to total dry matter in seedlings.

Paschall and Ellis (19), working with tropical soybean cultivars in Puerto Rico, observed that small-seeded cultivars have fewer internal seedborne fungi and, thus, may have better viability.

MATERIALS AND METHODS

The soybeans were grown at the Agronomy South Farm, University of Illinois at Urbana-Champaign, U.S.A., in the summer of 1978. Two cultivars, Williams (maturity group III) and Hodgson (maturity group I) were planted. These cultivars will be termed V_1 and V_2, respectively. Planting was on May 29 and, 3 weeks later, on June 20, 1978. These dates will be termed D_1 and D_2, respectively.

The experimental design was a randomized complete block, with the blocking arranged down the slope in the field. The following treatment combinations were replicated four times:

Cultivars 1, Planting Date 1 = V_1D_1

Cultivars 1, Planting Date 2 = V_1D_2

Cultivars 2, Planting Date 1 = V_2D_1

Cultivars 2, Planting Date 2 = V_2D_2

Field sampling commenced when pods were 3 cm long at any one node. Three plants were randomly selected from each plot and cut at ground level. All branches were removed and only the main stem used for further observations. Sampling continued twice a week until the plants were mature.

Each plant sample was measured and 10 cm segments marked off from the basal end upwards. The segments were numbered beginning with one at the basal end. Pods from each segment were removed separately and oven dried at 43° C, which was found to bring them to a steady moisture state. The total seed number and total weight per sample then were noted.

For testing seed size, three plants were selected at random from each plot in all treatments. Sampling commenced for six weeks. Later, the bulked samples were divided using five sieves of progressively smaller mesh size. Thus, up to six size classes were obtained from each sample. The smallest seed was categorized as class 1 and the largest seed as class 6 (Table 1). Each sample was dried at 25° C for 4 days and then counted and weighed. The 100-seed weight was computed.

Table 1. Seed Size Classes and Their Respective Diameter Ranges

Seed size class	Diameter range (mm)
1	4.5 or less
2	4.51 - 5.3
3	5.31 - 6.2
4	6.21 - 6.9
5	6.91 - 7.7
6	7.71 or more

RESULTS AND DISCUSSION

The increase in 100-seed weight over all dates of harvest is presented in Fig. 1.

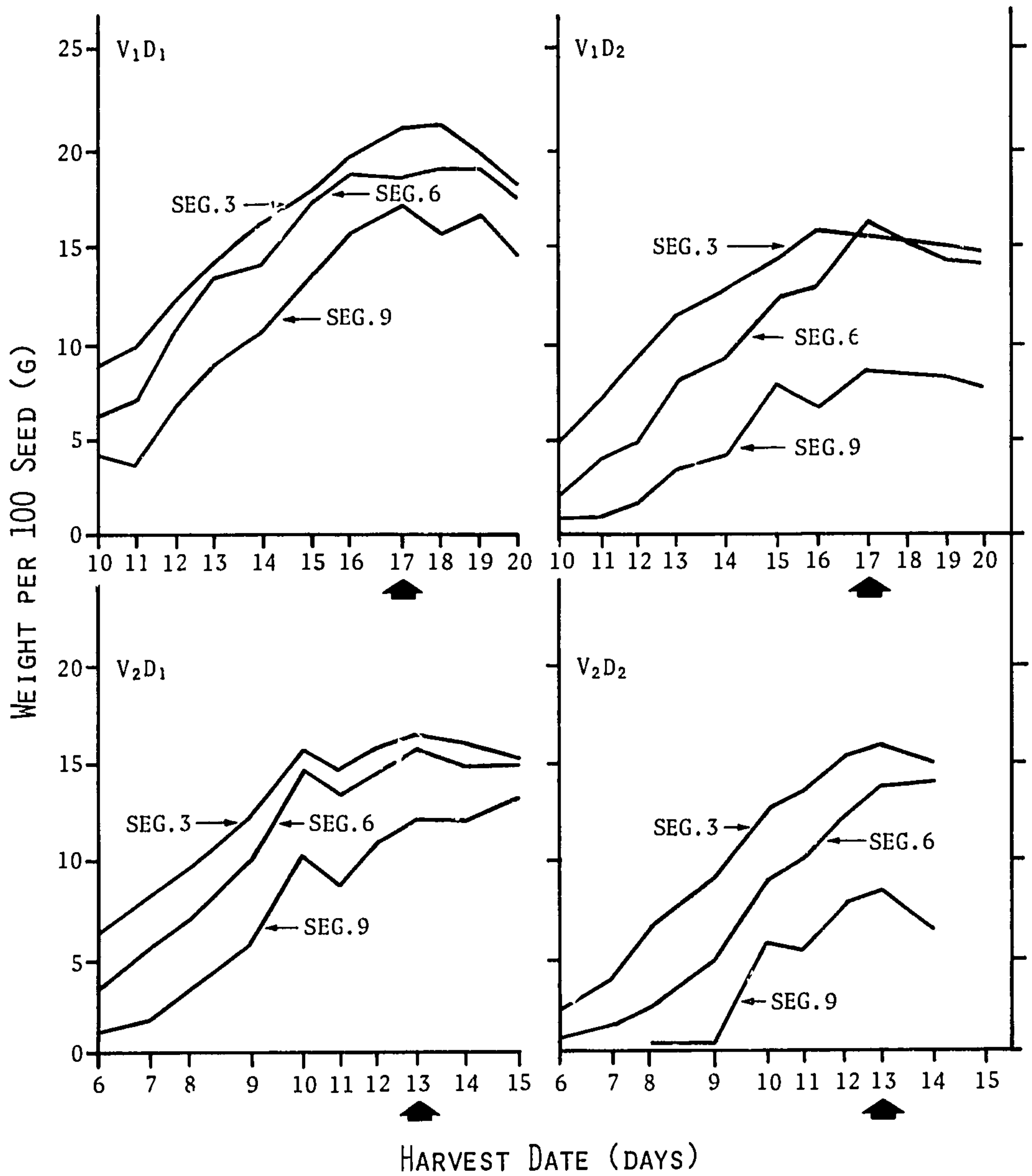

Fig. 1. Increase in 100-seed weight over harvest date in the four cultivar-planting date combinations. Only curves for segments 3, 6, and 9 are shown in each treatment combination. Arrows at harvests 17 and 13 in V_1 and V_2, respectively, indicate the dates of physiological maturity.

For purposes of statistical analysis of the data on 100-seed weight for V_1, only data for harvest numbers 10 through 17 and segment numbers 2 through 10 were selected. Similarly for V_2, only data for harvest numbers 6 through 13 and segment numbers 2 through 9 were selected. Data for both dates of planting in each cultivar were summed and each cultivar subjected to a separate analysis of variance.

In both cultivars similar trends were observed. Early planting gave a significantly higher (1-percent level) 100-seed weight in all segments (Table 2). The reduction in seed weight due to delayed planting was higher in V_1.

Table 2. Mean 100-Seed Weight at Maturity in Each Cultivar-Planting Date Combination

Cultivar	Planting date	100-seed weight (g)
Williams	D_1	17.59
	D_2	13.20
Hodgson	D_1	15.21
	D_2	13.57

In both cultivars at both planting dates, seed weight in each segment showed a highly significant quadratic relationship to position in the plant canopy. The smallest seeds were observed in the uppermost segments.

Within the grand period of growth, seed weight increased linearly with the harvest date. The segment-harvest date interaction was not significant in both cultivars, indicating that the rates of dry matter accumulation in seed of all segments are similar. The linear regression coefficients (slopes) for segments 2 through 9 over the earlier selected range of harvest dates are given in Table 3.

Table 3. Linear Regression Coefficients (Slope) Indicating the Relative Increase in 100-Seed Weight Per Day in Each Segment of Each Treatment Combination

Segment	Linear regression coefficients (increase in 100-seed weight/day (g))			
	V_1D_1	V_1D_2	V_2D_1	V_2D_2
2	0.412	0.443	0.407	0.547
3	0.532	0.458	0.442	0.567
4	0.528	0.522	0.493	0.604
5	0.570	0.573	0.536	0.581
6	0.569	0.581	0.522	0.564
7	0.525	0.482	5.537	0.619
8	0.593	0.380	0.506	0.493
9	0.594	0.340	0.476	0.504

These data show that the rates of dry matter accumulation in seeds per day in the uppermost segments are not higher than the rates for the lower segments. Thus, seeds in upper segments do not increase in weight faster than seeds in lower segments, and finally at maturity the upper seeds, which are initiated later, tend to be smaller.

Data from harvest numbers 17 (for V_1) and 13 (for V_2) were selected from a separate analysis of variance, since those were the dates selected as the dates of physiological maturity (Table 4).

The seed weight in cultivar 1 was significantly greater than the seed weight in cultivar 2 at both planting dates. Early planting gave significantly greater final seed weight in both cultivars in all segments. The data for the segments indicated a second-degree (quadratic) relationship to position in the plant canopy, which was highly significant. Seed weight tended to increase up to segment 3, 4, or 5 and then to decline progressively (Table 3).

Cultivar-planting date interaction was highly significant, which appears to be due to the reduction in seed weight with late planting that is much greater in late cultivar V_1 than in the early cultivar V_2. The cultivar-segment interaction also was nonsignificant, indicating that early or delayed planting does not change the difference in seed weight between segments.

The seed obtained from the six weekly samplings were sieved out into the six different size classes. Statistical analysis was done on the 100-seed weight and percent germination data for the sampling as well as seed size class. The seed size classes and their respective diameter ranges are shown (Table 1).

Early sampling resulted in reduced seed size as expected, and this is seen to be highly significant (1-percent level). The mean 100-seed weight at each sampling date is shown (Table 5). During the 35-day period of sampling, seed weight increased from 11.08 g to 19.18 g in the first planting of the late cultivar V_1, and from 8.80 g to 18.60 g in the second planting of the same cultivar. The difference between the first and last samplings of Hodgson (V_2D_1 and V_2D_2, respectively) was not as great. The analysis showed a highly significant cultivar-sampling date interaction.

The percent germination was high even in the early samplings (Table 5). Differences in percentage of germination in the cultivar-planting date combinations are nonsignificant. This indicates that both the early and late cultivars had high germination levels, even though seed weight was low in the early samplings.

Table 4. The 100-Seed Weight in Different Segments in the Four Treatment Combinations at Physiological Maturity of Seeds, Which Was Assumed to Be at Harvest No. 1? for V_1 and Harvest No. 13 for V_2

Segment no.	Height above ground (cm)	100-seed weight (g) V_1D_1	V_1D_2	V_2D_1	V_2D_2
2	10-20	17.61	13.72	16.04	16.11
3	20-30	21.10	15.42	16.59	15.70
4	30-40	19.39	16.38	16.67	14.79
5	40-50	19.32	16.62	16.91	14.07
6	50-60	18.65	16.20	15.67	13.87
7	60-70	17.50	12.64	15.03	12.49
8	70-80	17.35	9.40	13.66	9.86
9	80-90	16.95	8.60	12.39	8.30

Table 5. Mean 100-Seed Weight and Mean Percentage of Germination in Each Treatment Combination at Each Date of Sampling

Sampling		100-seed weight (g)				Germination (%)			
No.	Date	V_1D_1	V_1D_2	V_2D_1	V_2D_2	V_1D_1	V_1D_2	V_2D_1	V_2D_2
1	Sept. 5	11.08	8.80	15.85	13.95	96.3	96.8	95.0	95.8
2	11	13.78	11.95	16.30	15.93	98.6	99.4	96.7	95.1
3	19	17.75	15.83	16.95	16.83	97.4	98.6	93.6	97.8
4	26	19.80	17.20	16.50	16.10	97.3	97.5	95.4	96.7
5	Oct. 4	20.40	18.25	16.65	16.15	94.8	97.2	94.5	94.7
6	10	19.18	18.60	16.93	15.85	97.6	97.0	96.2	95.0

Table 6. Mean 100-Seed Weight and Mean Germination in Each Treatment Combination in Each Seed-Size Class

Seed-size class	Diameter (mm)	100-seed weight (g)				Germination (%)			
		V_1D_1	V_1D_2	V_2D_1	V_2D_2	V_1D_1	V_1D_2	V_2D_1	V_2D_2
1	4.5 or less	3.00	3.30	1.40	2.40	41.7	50.6	8.7	23.4
2	4.51 - 5.3	9.00	8.40	9.80	10.40	93.2	92.5	75.7	90.0
3	5.31 - 6.2	12.70	12.60	13.90	13.80	95.5	98.4	93.5	94.4
4	6.21 - 6.9	18.60	18.10	18.10	17.90	98.9	99.2	98.8	98.5
5	6.91 - 7.7	22.90	22.50	22.30	21.90	99.1	99.6	97.9	98.9
6	7.71 or more	26.60	25.00	26.40	16.40	99.3	100.0	100.0	100.0

Data for mean 100-seed weight and percentage of germination in each seed size class are presented (Table 6). It is seen that even th smallest seeds (less than 4.5 mm) whose lo. seed weight was 1.40 g to 3.30 g, had a considerable proportion of viable seed. The percentage of germination of 41.7 for V_1D_1, 50.6 for V_1D_2, 8.7 for V_2D_1, and 23.4 for V_2D_2 are presented (Table 6). In seed size class 2, the mean 100-seed weight was still quite low, but the percentage of germination was extremely high (over 90 percent in all treatment combinations).

The proportion of seeds in each size class at each sampling date was calculated. Increase in the proportion of medium-sized seeds was rapid as sampling proceeded. Treatment V_1D_2 within the first sampling date had less than 19 percent of the seeds greater than 6.2 mm in diameter. Most of the seeds fall into the first three small-size classes. By the last date of sampling, over 84 percent of the seeds were greater than 6.2 mm in diameter and fall into the medium and large seed-size classes. The medium-size class was predominant in all treatment combinations (Table 7).

Table 7. Diameter of Seed and Percentage of Total Seed Number in Each Seed-Size Class at Each Sampling Date

Seed-size class	Diameter (mm)	Percentage of total seed number					
		Sampling date					
		1	2	3	4	5	6
Cultivars 1, Planting Date 1 = V_1D_1							
1	4.5 or less	2.3	1.7	1.0	1.5	1.4	1.3
2	4.51 - 5.3	30.1	18.0	2.9	1.0	1.2	1.4
3	5.31 - 6.2	51.1	38.8	25.5	8.2	5.4	7.8
4	6.21 - 6.9	15.3	37.4	51.0	52.1	49.4	60.8
5	6.91 - 7.7	1.2	5.2	18.9	32.4	38.1	25.7
6	7.71 or more	0	0	0.6	4.6	4.3	3.3
Cultivars 1, Planting Date 2 = V_1D_2							
1	4.5 or less	7.3	1.2	0.5	1.1	1.1	0.9
2	4.51 - 5.3	51.[illegible]	18.2	5.6	4.3	1.9	2.5
3	5.31 - 6.2	40.5	63.0	33.5	23.8	14.7	12.3
4	6.21 - 6.9	0.7	17.2	56.1	56.8	62.2	58.0
5	6.91 - 7.7	0	0.5	4.2	13.0	19.3	24.9
6	7.71 or more	0	0	0	1.4	0.8	1.3
Cultivars 2, Planting Date 1 = V_2D_1							
1	4.5 or less	1.1	0.9	1.4	1.5	1.0	1.4
2	4.51 - 5.3	8.5	3.0	2.6	2.4	2.6	2.6
3	5.31 - 6.2	40.8	34.3	25.0	25.3	23.0	25.3
4	6.21 - 6.9	46.9	60.0	66.6	67.7	70.9	65.7
5	6.91 - 7.7	2.2	1.9	5.7	4.0	2.2	4.7
6	7.71 or more	0	0.4	0	0	0	0
Cultivars 2, Planting Date 2 = V_2D_2							
1	4.5 or less	1.6	1.2	0.8	1.6	1.0	0.8
2	4.51 - 5.3	16.6	5.2	1.5	3.6	4.7	4.8
3	5.31 - 6.2	56.7	38.7	25.5	32.8	31.6	35.5
4	6.21 - 6.9	25.0	52.1	67.9	60.6	58.9	55.8
5	6.91 - 7.7	0	3.5	4.9	1.7	3.9	2.6
6	7.71 or more	0	0	0	0	0	0.3

SUMMARY AND CONCLUSIONS

Harvesting three weeks prior to normal physiological maturity did not cause any appreciable loss in seed viability. Under certain circumstances, early harvesting may be advantageous. Although early harvesting may give rise to a larger proportion of smaller seeds, such seeds can still show good germination and may be used for planting. This fact may be especially useful in the tropics under small-scale cultivation, where farmers usually save part of their harvest for planting. Tropical weather conditions are unpredictable, and the onset of bad weather at the end of the growing season may necessitate early harvesting to save the crop from deterioration.

Within a given seed lot, there is quite a large variation in seed size. Results show that the largest proportion of seeds is in the mid-sized classes. Also, it was seen that early planting with consequently a longer growing period tends to give rise to a relatively high proportion of larger seeds. Larger seeds are produced in the lower part of the plant canopy, and the seeds and pods get progressively smaller up in the plant canopy. In addition, it was observed that the dry matter accumulation rates among segments were similar, thus giving rise to different seed sizes in different segments due to the fact that they start at different dates and end accumulation about the same date. Comparing these results, it is seen that a longer growing period would tend to increase the proportion of large seeds. Early planting gives a significantly higher seed weight. The highest amount of dry matter is accumulated in the lower part of the canopy, and seed weight progressively declines upwards. Since the rates of dry matter accumulation were similar in the segments, the variation in seed weights were due to the time period of dry matter accumulation. Early planting would therefore proportionately increase seed weight in all segments.

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DISCUSSION

P.S. Bhatnagar: You have shown that seed weight increases with the sampling date, but later there is a fall in seed weight at harvest. How do you explain the fact that the 96-percent germination at 35 days before harvest is reduced to 92 percent at zero days before harvest time?

C.D. Dharmasena: The fall in seed weight after maturity is possibly due to excessive drying and loss of moisture in the field. These data, to the best of my knowledge, are not statistically analyzed. There may be no significant difference between 96- and 92-percent germination.

F.C. Quebral: What was the medium used for germination?

C.D. Dharmasena: Wet "KIMPACK" on aluminum trays in a standard laboratory germinator. Temperature was 25° C.

B.B. Singh: Did you test viability of prematurely harvested seeds at various intervals during storage?

C.D. Dharmasena: No. The seeds were kept stored only for a short period in a dry, cold (50° F) room.

A. Rahman Khan: Since no statistical analysis is given in the data sheet, it is apparent that harvesting 10 days before physiological maturity is imperative because you get higher percentages of germination, emergence, and viable seed emerged as compared with harvesting at 7, 2, or 0 days before maturity.

C.D. Dharmasena: This higher percent germination at 10 days before maturity is possibly not statistically significant.

E.A. Kueneman: What is your definition of physiological maturity? Are you not referring to harvest maturity?

C.D. Dharmasena: The term "physiological maturity" has been given several definitions based on moisture percentage, seed color, seed size, pod color, and so on. I did refer to harvest maturity.

E. Pili-Sevilla: In the paper you have given, there is a column on emergence and viable seed emergence. What is the difference between the two?

C.D. Dharmasena: The percentage of viable seed emerged equals the percentage of emergence over the percentage of germination times 100.

Preharvest Environment: Weathering

C. HUNTER ANDREWS

There are distinct advantages to producing seeds in geographical areas that have favorable environments, i.e., low precipitation, absence of early morning fogs and/or heavy dews, and low relative humidity during preharvest and harvest periods. In such favorable climates, seed set and recovery is usually optimum; there is low incidence and severity of insects and plant and seed diseases. Germination and seed vigor are quite high. Hence, seed quality is usually good when produced under such favorable conditions. It is not uncommon, however, to find production of many kinds and large quantities of planting seeds in the same general area where the crop is grown for other commercial uses. Unfortunately, these geographical areas are frequently characterized by environmental conditions that are unfavorable and often detrimental to the production of high quality planting seed. Thus, the environment becomes implicated as a major factor contributing to the rapid deterioration of seeds.

Rapid deterioration and subsequent loss of seed quality is frequently, and probably universally, referred to as "weathering." This simply implies that the seeds have been exposed to the weather components, i.e., the environmental conditions existing in the field during the time of seed formation, development, and maturation. In other words, the seeds are "stored" on the plants until they can be harvested. While "stored" in this manner, they are undergoing the natural physiological deteriorative processes common in all biological systems (senescence) and, at the same time, the environmental stresses are imposing their influence. It is quite likely, then, that soybean seeds can, and quite often do, undergo severe field deterioration that lowers their quality.

This environmental "complex" encompasses an array of daily ambient conditions that vary widely according to a specific geographical location. Of the combination of environmental conditions that may exist at any given time, however, the one(s) we know to exert unfavorable stress(es) upon developing (maturing) seeds, either singularly or in concert, are high temperature and relative humidity (RH) and/or frequent or prolonged precipitation. Constituting additional increments of this "total environmental complex" are diseases and insects that seem to thrive in the same conditions that are detrimental to seeds, i.e., hot, wet climates. These conditions, of course, are quite typical of the subtropical and tropical zones of the world.

LITERATURE REVIEW

Historically, soybeans were produced in the northern regions of the temperate climatic zones of the world, where environmental stresses were relatively minimal. However, as the world demand for vegetable oil and protein continued to increase, soybean production spread rapidly into the warm (hot), humid production areas, and more recently into the tropical regions (15, 26). Rachie and Plarre (24) point out that soybeans are already well established in the tropics at intermediate elevations and in the subtropics. They hasten to point out, however, that it is questionable whether soybeans can be established in the low latitude, low elevation tropics and suggest that success depends upon favorable conditions and good management. Delouche (5) has documented many instances of poor seed quality in soybean seed and strongly contends that adverse weather conditions during the postmaturation, preharvest period cause moderate to severe seed quality problems. With such mounting evidence that the environment plays a significant role in affecting the quality of soybean seed, a closer examination of specific environmental factors seems in order.

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Environmental Moisture

Environmental moisture of significance in subtropical and tropical soybean growing regions takes the form of either heavy early morning fogs, dews, or rain. Under these conditions, relative humidity varies considerably but usually remains high during the warm, humid growing season. Additionally, as the fogs lift, dews dry, and rains cease, a hot, penetrating sun bears down upon the developing seeds. Soybean seeds are very susceptible to such extremes of wetting and drying (dehydration and rehydration). Such cycles, particularly during the latter stages of seed maturation, are quite detrimental to seed quality and, in fact, cause rapid deterioration (5). Table 1 shows moisture fluctuations and germination percentage of four prominent soybean cultivars of the southeastern United States as they were harvested at intervals during and shortly after field maturation.

As early as 1950, Moorse et al. (16) reported that exposure to periods of dampness caused soybean seeds to deteriorate. In bean seeds, which are morphologically similar to soybeans, Moore (15) reported that alternate rehydration and dehydration following field maturity caused necrotic areas in the radicle and cotyledons and hairline fractures across the hypocotyl. In evaluating the effects of various field environments upon soybean seed quality, Mondragon and Potts (14) and Burdette (2) determined that supplemental water sprays, either daily or once or twice weekly, increased the rate and degree of field deterioration. Deterioration was retarded either by protecting the maturing seeds from the ambient field environment or by removing them completely from it. In 1959 Howell et al. (10) concluded that rain in the field or a simulated rain on intact pods increased the moisture content of the seeds, which delayed dehydration and prolonged rapid respiration that was of a magnitude to reduce the amount of sugars and other stored materials in seeds. Although they failed to relate the significance of these results to seed quality, no doubt loss of sugars and other materials from the seeds lowers their quality.

Timely harvest of mature soybean seeds is extremely important in protecting and maintaining high seed quality. Harvest delays beyond optimum maturity extend field exposure and intensify field deterioration. Wet field conditions frequently cause harvest delays. Green et al. (7, 8) reported that, when soybean harvest was delayed due to rain after the seeds had initially declined to 13.5 percent moisture content, seed quality declined with subsequent reductions in germination and field emergence. Tekrony and Egli (26) reported similar declines in vigor when seeds were harvested even within 30 days after "harvest maturity," especially if hot, humid conditions prevailed (Table 2). Nangju (18) reported that harvest delays were accompanied by an increase in purple stain and cracked, wrinkled, and discolored seed. He proposed the use of "delay-harvest plus rainfall" to evaluate for resistance to field weathering. Paschal and Ellis (22) obtained reduced sand germination and field emergence of 7 and 14 percent, respectively, by delaying harvest two weeks. Costa (3) obtained highest seed quality when 95 percent of the pods were mature and lowest seed quality when harvest was delayed 14, 28, or 42 days after 95 percent maturity.

Table 1. Seed Moisture Content and Germination for Four Soybean Cultivars at Intervals during Field Maturation

Harvest date	Hill H_2O	Hill Germination	Dare H_2O	Dare Germination	Mack H_2O	Mack Germination	Lee H_2O	Lee Germination
				percent				
10/3	16	87	33	93	...	...	60	90
10/10	15	78	16	87	15	66	51	88
10/17	13	71	13	92	13	79	15	79
10/24	12	34	12	54	12	41	11	78
10/31	22	32	23	37	23	40	20	86
11/9	37	27	37	28	10	35	35	64
11/16	14	11	14	33	14	7	14	70
11/23	32	0	31	24	31	14	31	68
11/30	18	0	18	11	23	4	16	47
12/8	...	...	14	16	14	5	14	50
12/14	...	...	12	12	13	6	12	46

Table 2. Maturation Dates and Seed Quality at Physiological Maturity and at Harvest Maturity

Parameter	Cutler 71 1973	Cutler 71 1974	Cutler 71 1975	Kent 1974	Kent 1975
Physiological maturity					
Date	9/19	9/24	9/16	10/1	9/30
Germination, %	98	94	86	94	93
Harvest maturity					
Date	9/29	10/7	10/6	10/11	10/14
Germination, %	87	97	73	91	94
Desiccation, days	10	13	20	10	14

Note: Adapted from Tekrony, Egli, and Phillips(26).

Environmental Temperature

High temperatures coupled with high moisture (either RH or precipitation) exert severe stresses upon developing soybean seeds. Moorse et al. (16) stated that hot weather during seed maturation often resulted in seedcoat wrinkling, which reduced germination. When Costa (3) evaluated 18 soybean lines in Brazil, he found that an alternation of rain and hot weather accelerated deterioration, and high temperature during final stages of seed maturation caused green seeds that were low in quality. Potts and Mondragon (15) reported that plants that were shaded to reduce incident solar insolation by 50 percent produced seeds that deteriorated at a slower rate than did seed produced on unshaded plants. Similarly, Burdette (2) demonstrated that seeds harvested from plants removed from the field and stored in open-sided sheds were higher in quality than those that remained exposed to the ambient field environment. In both instances the reduced rate of "field weathering" was attributed to cooler temperatures and a more stable microclimate.

Environmental Diseases

Tropical and subtropical climates with high rainfall and temperature are favorable for rapid disease development. Thus, seedborne diseases become associated with particular environments and must be included as part of the total climatic pattern. Certain microorganisms are pathogenic to seeds, and increased infection obviously leads to a reduction in seed quality. In 1971 Nicholson and Sinclair (20) and Nicholson et al. (21) reported that the incidence and severity of fungal invasion of seeds is increased by "weathering," which lowers seed quality. Hepperly and Sinclair (9) demonstrated that germination decreases were accompanied by increases in the incidence of *Bacillus subtilis* and *Phomopsis sojae*. They concluded that seeds infected by *P. sojae* were low in quality, since they were distorted in size and shape, covered by fungal mycelium, and low in test weight. Wilcox (28) showed that a loss in seed quality was due to increased incidence of *P. sojae* and other fungi when soybean harvest was delayed.

In 1978 Paschal and Ellis (22) grew 24 soybean lines in Puerto Rico to determine the incidence and effect of fungal infection on seed viability under tropical conditions. Seeds were harvested at maturity and two and four weeks later. The incidence of fungi increased from 9 percent on seed harvested at maturity to 45 percent for seed harvested four weeks later.

Environmental Insects

Insect pests are a part of the environment and may cause severe damage to developing soybean seeds. Some pierce the pods and subsequently the seedcoats, while others actually destroy portions of the pods. If insects pierce the pod walls and subsequently the seedcoats, they may either transmit diseases directly to the seeds or provide openings through which subsequent invasion by pathogens may take place. In addition, these minute openings allow moisture to penetrate into the pod cavity, causing deterioration. Insects that eat large portions of the pod and destroy the protection it affords allow moisture and pathogens to attack the developing seed.

In studies with the southern green stink bug, *Nezara viridula* (L.), Todd and Turnipseed (27) infested caged soybean plants with various population densities to determine their effects on seed quality. Significant increases in seed damage occurred from population densities of one, three, and five bugs per row foot, and seed germination and emergence and seedling survival were significantly reduced by all degrees of damage. Likewise, other investigators (11, 12) have reported that heavy infestations of stink bugs at the early pod-fill stage cause drastic reductions in seed quality. Other insects that have been implicated in the reduction of seed quality in soybeans are bean leaf beetle, *Cerotoma trifurcata* (Forester), which transmits bean pod mottle virus (BPMV) (4), and *Piezodorus guildinii* (Westwood), which reduced germination and seed quality in Brazil (3).

CURRENT RESEARCH AND DEVELOPMENTS

Prospects for improving the seed quality of tropically adapted soybean cultivars are encouraging. An initial approach is to exploit the genetic variability that cultivars exhibit to differences in rates of field deterioration. Lassim's (13) work showed that certain cultivars possess differential rates of deterioration even though the cultivars matured at the same time. Paschal and Ellis (22) and Costa (3) provided additional evidence that substantial genetic variation exists in different cultivars for seed quality characteristics measured under tropical conditions. Cultivars with small seed size appear to be better adapted to some tropical climates. They have been reported to resist weathering and invasion by pathogens and to germinate and emerge better. Since some "weathering" resistant characteristics have been identified, breeding programs may concentrate on incorporating them into commercially acceptable cultivars.

Altering planting dates to allow the critical stages of seed maturation to coincide with favorable segments of the field environment may prove feasible. In a study on the effect of planting and maturity dates on soybean seed quality, Green et al. (7) found that when soybean plants were planted early so seeds matured during hot, dry weather, seeds produced were low quality. On the other hand, seeds from plants that were planted later and reached maturity after the hot, dry weather conditions had ended were high in quality. Investigations in this area have been initiated in Kentucky and Mississippi.

The use of systemic fungicides to provide some degree of protection against "weathering" pathogens has received considerable attention, and their commercial use in soybeans has spread to some areas of the southeastern United States. It has been pointed out that delay in harvest results in an increase in seedborne fungi and subsequently a reduction in germination (9, 18, 19). Ellis and Sinclair (6) used foliar applications of benomyl to reduce the incidence of seedborne fungi at maturity and suppress the increase of internally seedborne fungi. Investigations with such materials could prove beneficial; however, the economics of using them must be thoroughly studied.

Recent investigations by Potts et al. (23) revealed the influence of hardseededness on soybean seed quality. Comparisons were made between seeds of "Dare" and those of an experimental hardseeded line (D67-5677-1) that is similar to "Dare" in growth type and maturity. Hardseededness was beneficial in maintaining the viability of seeds remaining in the field for up to nine weeks after seed moisture initially declined to 20 percent. Resistance to moisture reabsorption by the hardseeded line was clearly superior to that of "Dare" (Table 3). Continuing work with the hardseeded line by Miranda has revealed similar results, and of particular interest is the fact that seeds of the hardseeded line exhibit very low levels of internally seedborne pathogens.

SUMMARY

In many ways seeds are a product of their environment, even though they exhibit specific genetic characteristics through their inheritance pattern. The complex of environmental conditions frequently overrides the expression of genetic characters, causing seeds to exhibit additional traits attributed to the environment (moldy seed coats, shrivelled seeds, split or wrinkled seed coats, or necrotic areas on the cotyledons). These traits lower seed quality, and the seeds are generally referred to as "weathered." To improve seed quality in subtropical and tropical soybean-producing areas, breeding programs should incorporate resistance to unfavorable conditions while continuing to stress the necessity for improved management and production practices.

CONSTRAINTS ON EFFICIENT PRODUCTION

Economically successful soybean production depends upon rapid and uniform emergence from the seedbed of equally healthy, competitive seedlings from only one planting. This ensures uniform and rapid growth, uniform maturity, and optimum yield. Serious problems arise when seedlings either emerge erratically over an extended period of time or fail to emerge to an acceptable stand. Replanting causes

Table 3. Effect of Field Environment on Two Soybean Cultivars in 1973 and 1974

Harvest date	Dare Moisture	Dare Germination	D67-5677-1 Moisture	D67-5677-1 Germination	D67-5677-1 HS	D67-5677-1 Total viable seeds
			percent			
1973						
10/8	21	86	16	90	8	98
10/11	15	90	11	61	31	92
10/14	12	89	12	60	35	95
10/29	16	93	11	57	40	97
11/5	32	5	22	39	47	86
11/12	17	51	10	30	62	92
1974						
10/4	16	94	10	82	15	97
10/12	9	99	9	50	46	96
10/19	10	90	8	45	46	91
10/26	9	91	7	35	59	94
11/2	13	86	9	44	49	93
11/9	10	72	8	41	46	87
11/16	16	63	9	42	46	88
11/23	12	54	9	49	39	88
11/30	14	53	11	41	43	84
12/7	14	51	12	43	38	81

tremendous losses in time, investments and overall production efficiency. In fields where farmers decide not to replant even a poor, thin stand, production problems will continue to plague them throughout the crop season. Weeds, diseases, insects, and environmental conditions will continue to make an initially poor stand even more unacceptable as the season progresses.

Thus, it is essential that increased emphasis be devoted to the production of high quality seeds that posses the potential to produce a profitable crop under an array of field conditions. Seed producers or seed production units must be established and tutored in acceptable seed production techniques to insure the availability of the necessary production input, that is, good healthy seeds. Emphasis also must be placed upon the necessity of handling the delicate soybean with care in view of its sensitive physiological and structural makeup. Incorporating good cultural and management techniques into specialized "seed production" programs should help resolve stand establishment problems with the commercial crop.

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DISCUSSION

R.B. Dadson: Tropical climates have either a season of hot, wet conditions or only hot conditions without rain. We suggest to farmers that they produce seed in the second season, even though it is hot but without rain. Is this correct?

C.H. Andrews: Yes, I agree. You cannot alter an environment, but you can take advantage of certain seasons that minimize environmental interactions. That is, it is better to grow soybeans during a hot season (irrigating if necessary) than during a hot, wet season.

Lian Zheng Wang: Do you mean that hardseeded soybeans are all good, viable seed?

C.H. Andrews: Yes. If you scarify hard seeds, they will produce normal, viable seedlings. We have found that nearly all of our hard seeds are completely viable.

B.B. Singh: After how many months of storage do the hard seeds become permeable and germinate without scarification?

C.H. Andrews: Hardseeded soybeans gradually become permeable over time in storage. We can expect that a large percentage of the hard seeds will become permeable from the time of harvest and prior to the next planting season. It has been shown that mechanical harvest (and possibly animal or hand threshing) will create sufficient scarification for germination.

Harvest Procedure and Damage: Effect on Seed Quality

M. D. TEDIA

Soybeans are being grown on an increasing number of hectares in tropical and subtropical environments. The rising need for protein has encouraged this increase in cultivation during recent years. In India the area increased from a few hundred hectares to more than 0.5 million hectares from 1971 to 1980. Soybean cultivation is expected to cover 2 million hectares by 1984-85 in the Madhya Pradesh state of India. Major producers, in 1976, were the United States, contributing 50 percent of the world's total production; the People's Republic of China, contributing 15 percent; and Brazil, contributing 14 percent. In the United States, the history of soybean harvesting has been traced from the mid-1920s through years of major improvements in the late-1960s and 1970s (9). But techniques of harvesting this crop in countries like India have been similar to those for other pulse crops. Harvesting is one of the most critical steps in the overall soybean seed production operation. The system for harvesting and threshing is entirely manual, as in India and China, or highly mechanized, as in the United States or some of the European countries.

Soybean seeds are very susceptible to mechanical injury, particularly during the combining operation. Soybeans at low moisure content (8 to 11 percent) and at high cylinder speeds usually are damaged. Cleaning losses of 10 percent or more often result from the mere removal of splits, and the germination percentage of clean seeds is frequently so low as to render them unfit for planting purposes.

Harvesting that results in mechanical damage to seeds is the area that needs the attention of researchers in tropical countries, as very little work has been done on this aspect.

HARVESTING PROCEDURES AND MECHANICAL DAMAGE

The mechanization of harvesting and threshing systems is characterized by the fact that the most prevalent and efficient systems are either entirely manual, as in India, China, and Korea, or highly sophisticated as in the United States (Table 1). In countries like China and Korea, where the primitive methods have been used for so long, harvesting is by short-bladed knives, which are used manually to break the individual stems at the height of 2.5 cm from the ground. Sickles are used for harvesting the crop in India. After harvesting, the crop is left in the field for a few days to cure. It is then removed to the threshing ground where it may be cured for two to three weeks. Threshing in some countries is done by using bamboo flails or by pulling a stone roller over the material spread over the ground with the help of horses or bullocks. In Japan, log rollers are used. Threshing is done by hand beating or by bullock treading instead of by using power threshers. Most of the mechanical damage is associated with power threshing or combining operations at various moisture contents and times of harvests.

Soybean seeds are very susceptible to mechanical injury. The seed coat of yellow cultivars is relatively thin, and the radicle lies in an extremely vulnerable position.

Injury results from impacts and abrasions sustained during harvesting and cleaning. Oatout (10) stated that mechanical injury sustained during threshing was responsible for a reduction in vitality of soybean seeds. Dongre (5) summarized investigations regarding soybean threshing.

A Vogel thresher obtained from the United States was used for threshing trials

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Table 1. *Summary of Soybean Threshing Investigations*

Method of threshing	Capacity (kg/hr)	Visual damage (%)	Grain loss (%)	Cleaning efficiency (%)
Hand beating and manual cleaning	2.30	1.61	9.73	100
Bullock treating and manual cleaning	20.30	2.43	1.05	100
Vogel power thresher, beater type	157.60	8.60	0.35	86.36
Swanson power thresher, rasp bar type	119.84	7.17	1.10	85.76
Soybean power thresher, closed concave (UPAU)	170.00	3.50	3.65	97

during the kharif season of 1967 at Jabalpur (7). The threshing unit in this machine consisted of a drum and a concave with fingers. Threshing with fingers on both the concave and the drum resulted in 9.5 to 14.8 percent damage to grain at all drum speeds from 300 to 700 rpm that were tried. Adjusting the tooth clearance did not help. Removal of all the teeth from the concave resulted in acceptable quality of threshing, except for the fact that some quantity of grain got lost with chaff, particularly at lower speeds. This is probably due to the vertical arrangement of the parts through which materials flow in the thresher. Soybean threshers are being designed at Pantnagar, and it is claimed that mechanical damage has been reduced to the extent of 2 to 5 percent. Tekchandani (15), in one of his unpublished papers, reported that soybean harvesting at the 15 to 20 percent moisture level that is reached in 105 to 120 days after sowing results in minimum harvesting losses. Sickle harvesting resulted in 1.5 percent loss, and reel-mounted mower harvesting resulted in 8 to 9 percent losses. These losses were aggravated by delayed harvesting. Singh et al.(14) and Tekchandani (15) reported the effect of combine cylinder speeds and seed moisture content on the mechanical damage of soybean seeds of different cultivars (Table 2).

It was observed that damage to grain was directly proportional to speed and inversely proportional to grain moisture content. Ankur was more resistant to damage than PK 71-21. Singh (13) reported that a more suitable cylinder speed for threshing soybeans with a thresher evolved at Pantnager, India. At 14 to 16 percent grain moisture content a speed of 500 rpm produces minimum damage and threshing loss. In the range of 10 to 12 percent grain moisture content, the cylinder speed should be in the range of 300 to 400 rpm.

The damaging effect of the combine harvester on seed germination and vigor has been demonstrated (6). Hand harvested lots had a much higher viability than machine harvested lots of the same cultivar when both lots were harvested on the same day. The effects of harvest methods and combine cylinder speeds are presented (Table 3).

The differences in germination were ascribed primarily to differences in seed coat damage. Harvest damage was least when moisture content of the seed was 13.5 percent and slow cylinder speeds were used in threshing. Colby et al. (2) reported that decreases in germination resulted from improper threshing, cleaning, and handling when soybean moisture content was low. Seed damage and loss of viability increased when moisture decreased to less than 13 percent. Barger and Weber (1) found that beans are injured in the cylinder of the combine, where the beans are separated from the pod. Only 56 percent of the injured seed produced healthy plants. Park and Webb (11) made a study of soybean harvesting losses in South Carolina during the 1958 season. In a few cases, they found excessive seed damage as a result of poor adjustments of the combine. Lamp et al. (8) studied methods for improving soybean harvesting. They found that combining when the kernels were above 12 percent moisture and pods were dampened by dew or rain resulted in the greatest improvements in harvesting efficiency and minimized seed damage. High cylinder speeds thought by many to be necessary for complete threshing were very injurious to the seeds. Germination percentage based upon whole, undamaged seeds combined at high cylinder speeds was only 73.[illegible] percent. While this degree of injury is not of much concern

Table 2. Effect of Cylinder Speeds and Seed Moisture at Harvest on Damage of Soybean Seeds

Cultivar	Seed moisture at harvest (%)	Damage percentage Combine cylinder speed (rpm) 300	400	500	700	900	1155
Bragg	13.5	..	..	..	4	5	12
	12.2	..	..	..	5	24	48
Ankur	11.5	0.56	1.75	2.53	..	..	..
	14.0	0.49	1.66	2.5	..	..	..
Pk 71-21	11.5	1.85	2.75	4.3	..	..	..
	14.0	0.95	2.35	3.6	..	..	..

Table 3. Effects of Harvest Method and Combine Cylinder Speed on Soybean Seed Characteristics

Cultivar	Harvest method/ cylinder speed	Laboratory germination (%)	Field emergence (%)	Splits (%)	Cracked seed coat (%)
Shelby	Hand harvest	50	35	..	6
	500 rpm	51	39	4	32
	700 rpm	46	34	8	38
	900 rpm	46	29	20	49
Harosoy	Hand harvest	83	76	..	5
	500 rpm	79	74	1	11
	700 rpm	76	74	2	16
	900 rpm	76	69	6	27

as regards market beans, it is of vital importance in the case of beans meant for seed.

Delouche (3) states that the optimum harvest date for soybean seeds is just as soon as possible after their moisture content drops to 13 or 14 percent (Table 4).

Mechanical damage during harvesting, handling, and processing causes not only splitting of the seed but also cracking of the seed coat and radicle. The latter is more important in terms of germination because splits can be separated out of the seed lot by processing while cracked seeds

Table 4. Relation of Seed Moisture Content and Force of Impact (Height of Drop) to Loss of Germinability of Soybean Seed Dropped onto a Hard Surface

Seed moisture content (%)	Height of drop 0	1.52	3.05	6.10
	germination (%)			
8	98	88	78	70
10	98	90	82	73
12	98	97	94	87
14	98	97	97	97

cannot. General recommendations as given by Delouche (3) for minimizing damage in combine harvesting are:

1. Harvest just as soon as possible after seed moisture content drops to 13 to 14 percent;
2. Combine at a uniform speed;
3. Adjust the cylinder to the speed at which complete threshing is achieved, but no higher;
4. Adjust the cylinder speed slightly higher in the morning, when beans are more difficult to thresh because of dew, and lower it during the afternoon, when beans are dry and thresh more easily.

From this discussion, it is evident that most of the work on the combining of soybeans has been done in the United States. The efficiency and practicability of power threshers have yet to be demonstrated to farmers in tropical and subtropical countries.

CURRENT RESEARCH AND DEVELOPMENT

Experiments are being conducted at Agriculture University, Jabalpur, India, on various harvesting and threshing methods, namely, stick beating, bullock treading, beater and rasp bar type cylinder power threshers. Work is still to be done on black-seeded cultivars of soybeans that are known to have hard seed coats. A combine manufactured by Vicon Co. Ltd., Bangalore, India, has recently been tried and proved to be unsuccessful because of a reported wrapping of the crop on the auger and a high percentage of damage to seeds, even with cylinder speed and concave clearance adjustments (Dass Tractor Training Station, Budhni: personal communication).

Large-seeded cultivars seem to be more susceptible to seed coat damage. But genetic differences in damage susceptibility exist between cultivars of the same seed size. The black-seeded cultivar of soybean grown in India is to be harvested at a relatively high moisture percentage, that is, at about 50 percent leaf fall stage. If this cultivar is allowed to stand in the field until the moisture decreases to 13 to 14 percent, the shattering losses are more than 50 percent.

Efforts to reduce threshing damage have resulted in the development of rotary threshing equipment in the United States. Rotary combines have one or more longitudinal rotors to replace the conventional cylinder and straw walkers for threshing and separating grain from crop material. Because the material is subjected to less impact with a rotor than with a conventional cylinder, threshing action is reported to be more gentle (4).

Nave (9) has reviewed the recent innovation and current status of soybean harvesting equipment. In a study of Saij Paul et al. (12), the seed quality of soybeans harvested with a Sperry New Holland TR 70 rotary combine was compared with that of soybeans harvested with a Sperry New Holland Model 1400 conventional rasp bar cylinder combine. In most instances, soybeans had a higher germination percentage when harvested with the rotary combine than with the conventional combine.

Cylinder losses and damage can be prevented by carefully checking the condition of the harvested beans and varying the cylinder speed accordingly. The higher the moisture, the greater the cylinder speed needed. Conversely, slow cylinder speeds are necessary to prevent seed coat injuries to low-moisture soybeans.

CONSTRAINTS

Very little work has been done on seed quality as affected by harvest and threshing devices in tropical countries. The author has seen 15 to 20 percent splits in soybean seeds produced and threshed with a locally made thresher in Indore District of India.

In recent years, attempts have been made to encourage large scale cultivation in India for commercial purposes. Commercial utilization of soybeans is gaining importance. If good quality seed with a good vigor index is to be produced, threshing and harvesting methods have to be adopted that will cause less damage to the soybean seed. Studies have to be conducted taking into account the impact caused to embryo by the use of all these traditional and sophisticated harvest methods in tropical countries. There is an immediate need to develop post-harvest technology and harvest and threshing equipment for small- and medium-scale farmers in order to get good quality seed. The small and marginal farmers in India who cannot afford a combine must be provided with bullock-drawn mowers and power threshers. Cultivars differ in damage susceptibility and resistance to weathering. Harvesting and threshing machines that will cause less damage to soybean seeds of different cultivars need the immediate attention of research workers in tropical countries.

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Genetic Differences in Soybean Seed Quality: Screening Methods for Cultivar Improvement

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Obtaining consistently good plant stands is particularly difficult in the tropics, where seed deterioration is common due to unfavorable pre- and postharvest environmental conditions. Conditions such as high soil temperatures and the crusting of the soil surface at the time of sowing also contribute to poor plant establishment, especially when seed vigor is low.

This paper, in addition to describing cultivar differences in seed quality that have been identified, will discuss breeding considerations such as heritability and screening methodology relevant to incorporating good seed quality into adapted, high-yielding genetic backgrounds.

CAUSES OF SEED DETERIORATION

The causes of seed deterioration can be pathological, physiological, or mechanical. These causes frequently occur in combination and act synergistically to reduce seed vigor. It appears that pathogens frequently play a major role in seed deterioration prior to harvest or "weathering." Their effect during seed storage can be great, but it is often secondary to the deleterious physiological changes that occur as seeds age (3). This information provides a useful framework to plant breeders developing cultivars resistant to preharvest or postharvest deterioration of seed, or both. Thus, breeders screening cultivars for resistance to "weathering" must create a uniform environment suitable for pathogen establishment, while this is not necessary when screening for seed storability.

SCREENING METHODS AND ASSESSMENT OF SEED VIGOR

In order to evaluate varietal differences for resistance to seed deterioration, one must have a means of assessing seed vigor after weathering or storage stress. Assessment of vigor has been problematic for commercial seedsmen, who require information about seed vigor in order to market a quality product. Seedsmen have found that a laboratory germination test is often not a good indicator of stand establishment (7, 42), especially when seeds are at an intermediate level of deterioration. The importance of vigor assessment has spawned considerable research, and a number of methods have been proposed. For breeders who must evaluate thousands of breeding lines, the method must be rapid, repeatable, and inexpensive. Unlike commercial seedsmen, who require a vigor score to be quantitatively repeatable across different seed laboratories, breeders are looking primarily for relative cultivar differences after seeds are subjected to stress.

The basic premise behind most vigor tests is to subject seeds to stress, causing weak seeds to perform poorly. Various kinds of stress have been suggested. Some methods are more applicable to breeding than are others; commonly used or promising methods are discussed.

KINDS OF STRESS PROPOSED FOR SEED VIGOR ASSESSMENT

Seed Storage (Aging Seeds)

For breeders developing lines with inherently good storability, an obvious method of stressing seeds is to subject lines to prolonged storage. It may frequently require 6 to 12 months of storage to clearly discern which soybean lines store well. This delay prevents breeders from advancing more than one generation per year. When time is not "of-the-essence," prolonged storage is perhaps the best way to determine lines with the best storability.

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Accelerated Aging Stress

The method proposed by Byrd and Delouche (5) involved keeping seeds at 42° C and 100 percent relative humidity (RH) for 48 hours, followed by a laboratory germination test. They found that accelerated aging clearly distinguished seed lots that had been stored various lengths of time but that had similar laboratory germination scores. At IITA we evaluated accelerated aging as a method of identifying cultivars and breeding lines with inherent storability (46). We found fungal growth on seeds to be a problem with the "standard" procedure. However, when the RH was lowered from 100 to 75 percent, the fungal growth and cross-contamination of seed was sufficiently reduced. By storing seeds at 75 percent RH and 40° C for six weeks, we could predict reasonably well which lines would have good storability. Parrish and Leopold (36) reported physiological changes in seeds subjected to accelerated aging similar to those reported for seeds stored under more normal conditions. Therefore, it seems apparent that accelerated aging can be applied to freshly harvested seed to distinguish which lines have the best inherent storability. Great care must be taken to ensure that lines being compared are subjected to the same preharvest conditions. We currently harvest breeding lines when pods begin to turn yellow: remove all leaves and hang plants in a covered shed. After pods dry, we thresh and subject them to 75 percent RH, 40° C, for six weeks. Check cultivars of both good and poor storability are grown along with the breeding lines and are included in the accelerated aging test.

Cold Stress

This stress test involves sowing seed into soil-filled boxes equilibrated at 10° C and held at this temperature for seven days before transferring the boxes to 25° C. Emergence scores are recorded after an additional four to seven days. Although cold stress appears very useful for evaluating seed lots of the same genotype for ability to emerge in the field (25), the test is undesirable for screening tropical soybeans for inherent storability because the storability would likely be confounded with tolerance to cold, a characteristic not required. Further, it would be difficult to handle numerous breeding lines without immense cold room facilities.

Hot Water Pregermination Stress

Seeds are soaked for 70 seconds in 75° C water and then rinsed in tap water before evaluating by germination or emergence. This test appeared promising in initial experiments at IITA, but in testing a wide range of cultivars we found some lines that performed well under ambient storage but poorly under hot water stress. Lines tolerant to hot water also were tolerant to ambient storage. Thus, hot water stress would be an acceptable method for screening for storability if the breeder is willing to discard some segregants with good storability.

Osmotic Stress

Heydecker (18) and Hadas (16) have suggested that germination of seeds in polyethylene glycol solutions may provide an indication of seed vigor. Osmotic stress would not be likely to provide the breeder a test for inherent storability, but it could be a more accurate test for predicting seed vigor than a standard laboratory germination test after breeding lines are subjected to other stresses; more research is required.

Thermostress during Germination

Cole (6) reported that, by planting seeds across a thermogradient, he could develop a seed vigor index based on rate of germination at different temperatures and that the vigor index score gave similar ranking of seed lots of *Zea mays* L. as the accelerated aging test. Whether high temperature germination can reflect inherent storability of freshly harvested seed has not been examined. Thermostress during germination might provide valuable information about cultivars that have been aged either by normal storage or by accelerated aging, because it would subject the seeds to a stress (temperature) that is frequently imposed on soybeans sown in the tropics.

Methanol Stress

Musgrave et al. (31) found that a two-hour soaking in 15 to 20 percent methanol caused physiological changes in soybean seeds similar to those caused by accelerated aging. Because their comparison involved only seven cultivars, and three of those had unstressed germination below 40 percent, we repeated the experiment using 51 lines with unstressed emergence greater than 80 percent. We found quite a good relationship (r = 0.60**) between emergence following methanol stress and following accelerated aging. A few lines with poor emergence following methanol stress performed well under accelerated aging. It appears that the methanol stress test may provide a rapid screen for inherent storability if a breeder is not overly concerned that he might discard a few good entries. However, this test should be compared with ambient storage results before its usefulness as a breeding (screening) method is confirmed.

METHODS OF EVALUATING SEED OR SEEDLING VIGOR FOLLOWING STRESS

Laboratory Germination Test

A laboratory germination test is very frequently used by seedsmen and physiologists to assess the effects of stress applied during vigor tests. This test has the advantage of providing uniform conditions for all lines under evaluation. However, for a large breeding program where thousands of lines are to be evaluated (we evaluated over 50,000 and 34,000 breeding lines for storability in 1979 and 1980, respectively), a very large number of germination incubators would be required.

Field Emergence Test

Following the application of stress, such as a modified accelerated aging treatment (75 percent RH, 49° C) for six weeks, seeds are very weak, and variability of soil characteristics in the field can have rather large effects. In 1979, we performed field emergence tests on aged breeding lines and found variability within and among fields to be excessive for cultivar screening.

We have been able to get consistent emergence counts by sowing in a screenhouse (20 m x 20 m) pipe frame structure with a nylon net covering. Prior to sowing, a small amount of grass cutting was incorporated into the soil with a hand hoe to keep the soil friable. Furrows of 3-cm depth were made on a level seedbed. After placing seeds, the furrow was carefully covered with loose sandy soil and a light mulch was placed on the surface before the soil was wetted. About 5,000 breeding lines can be evaluated in such a screenhouse every two weeks.

Tetrazolium (TZ) Test

This test involves soaking seeds in TZ, cutting soaked seeds, and evaluating individual seeds for straining patterns. Seeds are generally categorized subjectively into sound or unsound seed. In addition to being subjective the TZ test is too time-consuming, making it generally unacceptable for breeding purposes.

Seedling Growth Rates

Seedling weight at seven days may reflect general vigor of stressed seed among seed lots of the same cultivar, but Byrd and Delouche (5) found radicle-hypocotyl length to be a less sensitive index of seed deterioration compared with accelerated aging, cold stress, or hot water stress. Also, differences in seedling weights among various genotypes may reflect genotypic differences not related to seed quality, such as the rate of inbibition or initial seed size.

Characteristics of Seed Leachate

It has long been known that cell contents of deteriorated seeds will leach out of soaked seed (19) and that the amount of solute leached is often related to the degree of seed deterioration. Consequently, measuring the electrical conductivity of leachate has been proposed as a vigor test and has been shown to be inversely related to field emergence for *Pisum* (29) and for soybeans (47). Research at IITA (unpublished) indicates that seed—simulated by different numbers of seeds soaked—has a great effect on conductivity or optical density (OD) readings of leachate. Transforming conductivity readings by dividing by seed weight greatly reduces the effect of seed size.

We investigated also the effect of seed coat color on conductivity and OD readings. Removal of seed coat produced a similar increase in conductivity for a yellow-seeded cultivar as for a black-seeded cultivar. The OD readings of leachate from a black-seeded cultivar were much higher when seed coats were present, but OD readings were higher when seed coats were removed from a yellow-seeded cultivar. Thus, one would have to remove seed coats for OD measurements on lines with variability in seed coat pigmentation. Physiologists using OD measurements on seed leachate generally remove seed coats before soaking (39). Although seed coat pigments do not appear to influence conductivity readings, it appears necessary to remove seed coats if one is screening breeding lines with cultivar differences in seed coat permeability. This step would not be practical for breeders who must evaluate thousands of breeding lines.

Levengood et al. (27) reported a method evaluating conductivity of individual seeds that are partially imbibed and discussed the development of a high speed sorter to select out seeds with low conductivity. Such a system, if developed, might be useful to breeders, permitting use of bulk population breeding methods.

Takayanagi and Murakami (43) proposed measuring sugar quantities in leachate using urine sugar analysis paper to detect differences in seed vigor among seed lots. While this method may have merit for within-cultivar comparisons of different seed lots, it would not likely be very efficient for between-cultivar evaluation because of inherent differences in seed composition unrelated to seed vigor.

SEED STORABILITY

Loss of seed vigor in storage is a problem for many crops, but it is particularly severe for soybeans. In most tropical regions, both the lack of controlled seed storage facilities and ambient conditions characterized by high temperatures and high relative humidity frequently result in poor stand establishment.

Cultivar Differences in Storability

In spite of the importance of the storability problem of soybean seeds in the tropics, very little work in the past has been done by plant breeders to alleviate the problem. Presently, the major thrust of the Soybean Improvement Program at IITA is to develop tropically adapted cultivars with superior storability.

One-hundred cultivars were harvested under dry conditions and stored for 200 days at 12° to 18° C. Five of the 100 lines tested—TGm 351, TGm 273-2, TGm 210-1-2363, TGM 294-4270, and CES 407 (21)—had good emergence. Several other lines were identified to have good storability the following year (22). TGm 236-5, TGm 683, and TGm 297-2-4243 had emergence scores between 40 and 45 percent after 120 days storage at 75 percent RH and 28° to 30° C. Other lines, primarily those of Indonesian origin, such as TGm 737, TGm 685, TGm 693, TGm 739, and TGm 623, had even better storability. IITA scientists have demonstrated that lines with good storability can be identified by subjecting freshly-harvested unweathered seeds to 40° C and 75 percent RH for about six weeks (2, 24). This modification of the accelerated aging test allows breeders to advance at least two generations per year.

Inheritance of Seed Storability

The storability of seeds in a genetically segregated population seems to be governed to a considerable degree by the genotype of the mother plant from which the seed is derived (24). F_1 seeds or reciprocal crosses involving parents with good and poor storability were subjected to modified accelerated aging. When TGm 737 was used as the female, the stressed seeds showed 25 percent emergence, while, when Bossier was used as the female, the emergence was 0 percent. Other F_1 seeds were subjected to hot water stress. Emergence with TGm 737 as the female was 100 percent; when Bossier was the female, the emergence was 75 percent. The frequency of self-seed was only 3 percent in these crosses, and, therefore, the reciprocal differences cannot be explained by failure to make cross pollinations. Reciprocal differences were not seen in aged F_2 seeds, suggesting that the maternal plant influence was not under cytoplasmic gene control. Lindstrom (28) found noncytoplasmic maternal plant influence to determine the storability of sweet corn inbreds. Other seed characteristics in soybeans, such as percent of protein, are under maternal plant influence

Parent-offspring regression (narrow sense heritability) studies are now under way at IITA to determine the efficiency of selection at different generations. Although results are not yet available from this study, we have been able to recover numerous breeding lines with good storability from crosses of high-yielding types with parents having good storability. Most of the sources being used at IITA for good storability are viney, lodge easily, and shatter badly. Several cycles of crossing may be necessary to recover many lines with all the characters needed for a useful, improved cultivar.

FIELD WEATHERING–FIELD DETERIORATION

High temperatures and high humidity during pod maturation predictably result in poor seed quality. By carefully matching varietal maturity (days from planting to harvest) and rainfall patterns, one can often select sowing dates that will minimize field deterioration. Other management practices may also reduce seed weathering. Andreoli and Ebeltoft (1) reported that by applying defoliants (glyphosphate or paraquat), they could speed up plant maturation and the dry-down time of soybean seeds, which resulted in better seed quality. Foliar applications of systemic fungicides have been suggested, but their protection is often inadequate (33), and the operation is expensive and difficult in many developing countries. In some geographical regions, the termination of a rainy season cannot be predicted with much precision. It is primarily in these regions that varieties with resistance to field weathering could be useful.

Screening methods that will distinguish resistant cultivars are required. One common method is to delay harvest after plant maturity and then assess the quality of seed either by visually scoring weathered seed, by examining incidence of internally seed-borne fungi, by using seed vigor tests mentioned above, or by using a combination of these assessment methods. A major difficulty in using the delayed harvest approach is applying the same environmental stress conditions to cultivars of different maturities. At IITA, we have been evaluating the effects of using daily overhead irrigation, the effects of preplanting a susceptible spreader row to provide a broad spectrum of fungi capable of weathering seed, and the effects of spray-inoculating plants with *Phomopsis* sp., a fungal pathogen known for its deleterious effects on seed prior to storage (35). Both spreader rows and daily sprinkler irrigation beginning at the onset of pod-fill resulted in loss of seed viability. *Phomopsis* spp. inoculation did not significantly affect subsequent seedling emergence. Though spreader rows and overhead irrigation may be useful for accelerating weathering, we failed to detect improvement in screening precision; treatments did not reduce the error term variance. Using the spreader row and overhead irrigation techniques described by Noudofinin (35), we screened 76 germplasm entries for resistance to field weathering at IITA during the dry season in 1980. Cultivar differences were highly significant (Table 1). Several of the best lines (TGm 737, TGm 685, TGm 693, TGm 623) are among the lines identified as having superior seed longevity in storage. Seed size was negatively correlated ($r = 0.67^{**}$) with emergence following weathering stress.

We are beginning to investigate artificial seed-weathering methods that will minimize effects of variable pod maturity on the same plant and effects of different maturities of lines being tested. Yellowing pods were pulled from test plants and placed 1 cm apart on a metal incubator tray. These pods were kept for 7 days at 30° C and with 12-hour cycles of 85 to 90 percent RH before final drying underambient conditions of approximately 28° C, 75 percent RH. Averaged across seven cultivars and six replications, the emergence scores were 60, 40, 20, and 16 percent for prompt harvest, two weeks' delayed harvest, four weeks' delayed harvest, and one week's inoculation, respectively, because differences for emergence at four weeks' delayed harvest and one week's incubation were not significant. We were unable to determine the relationship between the two methods. More research is required to develop a uniform field-weathering screening method.

Resistance to Seedborne Pathogens Involved in Field Weathering—Purple Seed Stain

In 1974 and 1975, scientists at AVRDC (24) screened 1,200 accessions against purple seed stain and reported the following entries to be resistant: Harosoy, Palmetto, Hidatsa, PI 248400, PI 181537, PI 200508, PI 200479, PI 238926, White Biloxi, Giant Sleeves, Kaoshiung No. 3, Lee, Sumbing, Aracadion, Pochal, No. 208, H15, L-?06-4-M(2)-10-M(6), Fukuzu, Austin, Ross, Shin 2, Takiya (Waseshu), K0309, Bikuni.

Nangju (32) reported that Improved Pelican was resistant to purple seed stain disease and that Improved Pelican maintained a higher germinability after delayed harvest than Hardee, Kent, or Bossier. Wilcox et al (47) reported PI 80837 to be very resistant to *C. kikuchii* and, from progeny evaluation of a cross between PI 80837 and the susceptible line Amsoy, concluded that resistance was highly heritable. Breeders wishing to inoculate for a uniform screening should do so at the young pod stage (40).

Diaporthe phaseolorum var. sojae (Phomopsis sp.) (Dps) is generally considered a primary causal organism responsible for loss of germinability in field-weathered seed (34). PI-82264 of group IV maturity was found to be resistant to Dps (44). PI-82264 was crossed with Lee, and progenies were selected with tolerance to field weathering. Cavinees (personal communication) was unable to get agronomically good lines from the cross, and, apparently, further genetic recombination was not attempted. Field emergence data presented by the same authors suggested that Dare may be more resistant to weathering than Hill or Hood. However, Ellis et al. (9), examining seed lots of four cultivars, reported Dare to have a very high percentage of internally-borne fungi.

Preliminary observations (8) suggested that Hill may have some level of resistance to Dps, but the data for cultivars, as presented, was confounded with seed lots (locations); additional information is required for confirmation. Foor et al. (11) examined seed lots of 12 cultivars grown over three years in Illinois and found no differences among cultivars. Hymowitz et al. (20) listed 19 cultivars with resistance to pod and stem blight caused by Dps. It was not reported whether any of these 19 lines had seed

Table 1. Seedling Emergence of 15 to 75 Soybean Lines Most Resistant to Field Weathering: Plants Subjected to Humid Conditions at Onset of Seed Fill and Harvested at Maturity and Again Two Weeks Later

IITA	Name	Emergence (%) First harvest	Emergence (%) Second harvest	Seed color	Seed size (g/100 seeds)	% hard seed (1 hr. soaking)
TGm 1171	AVRDC 8457	97	91	black	6.1	70
TGm 737P	INDO 243	94	81	black	8.3	42
TGm 705	INDO 169	94	83	yellow	10.6	5
TGm 715	INDO 195	93	79	yellow	10.2	0
TGm 712	INDO 188	92	71	yellow	9.3	0
TGm 706	INDO 173	92	81	black	9.7	63
TGm 693	INDO 153	91	72	black	9.6	79
TGm 623	INDO 9	90	83	yellow	9.6	0
TGm 685	INDO 131	90	84	black	10.3	60
TGm 730	INDO 226	91	84	black	9.3	15
TGm 737W	INDO 243	91	77	black	15.3	23
TGm 742	INDO 255	93	71	black	9.3	48
TGm 1063	AVRDC 3477	90	80	green	8.1	0
TGm 993	AVRDC 2106	89	84	yellow	12.2	0
TGm 918	ORBA	89	78	yellow	14.7	12
TGm 80	Bossier[a]	67	40	yellow	19.2	0
TGm 479	Jupiter[a]	47	27	yellow	17.5	2
TGm 7	Improved Pelican[a]	54	11	yellow	15.2	3
Mean		68	55	(61 yellow)		
Range		22-97	11-84	(12 black)	8.3-19.2	0-79
LSD (0.05) = 21				(1 brown)		
				(2 green)		

[a]Controls

resistance to Dps or whether any of the lines were resistant to field weathering; further evaluation is required.

Pascal and Ellis (37) evaluated 21 lines thought to have some resistance to field weathering along with three checks (Jupiter, Hardee, and PI 240672). Some of the lines most resistant to Dps and to weathering were PI 205912, PI 239235, PI 279088, PI 219653, PI 204331, PI 205907, PI 259539, PI 205098, and PI 341349. Of the commercially important cultivars in the test, Improved Pelican performed better than Arisoy, Hardee, or Jupiter. This observation supports that of Nangju (32) that Improved Pelican is relatively resistant to field weathering.

Ndimande et al. (33) found two black-seeded accessions of Indonesian origin, TGM 685 and TGm 686, to be more resistant to field weathering than Bossier or TGm 294. Bossier is of U.S. origin, and TGm 294 is a derivative of a cross made by Dr. Camacho in Colombia. Parents of TGm 294 are believed to be of U.S. origin. TGm 685 and TGm 686 were more resistant to Dsp than Bossier or TGm 294. TGm 685 was more resistant to *Colletotricum dematium* var. *truncata* and to *Cercospora kikuchii* than TGm 686 was. It is of interest that TGm 685 also has consistently performed well in storability tests at IITA. Storability of TGm 686 has been more sporadic, sometimes storing well, other times storing relatively poorly. It may be that when storage results of TGm 686 were poor, the seed was weak due to pathogen infection.

Resistance to Weathering Associated with Hardseededness (Seed Coat Impermeability)

Nonpathological aspects of field deterioration include subtle changes in physiological characteristics, such as loss of membrane integrity, that are normally associated with loss of seed vigor during storage. Additionally, alternate wetting and drying of seeds in the final stages of maturation leads to seed coat cracking and physical disruption of embryonic tissues. Thus, frequent rainfalls and heavy dews contribute to losses in seed quality. Soybean cultivars with high percentages of impermeable seed coats are less prone to weathering (38). Miranda (30) suggested that hardseededness in D67-5677-13 may have provided protection from seedborne fungi as well as from nonpathological deterioration. In work of both Potts (38) and Miranda (30), the original source of the hard-seededness characteristic was PI 163453.

Hard-seededness is a form of dormancy. If seed coats are extremely impermeable and if a method of uniform scarification is not developed, poor plant stands can be expected. On the other hand, if lines can be found that are relatively slow imbibers, perhaps some resistance to weathering can be realized without difficulties of seed imbibition at planting. To test this we screened soybean germplasm and identified 28 lines with differential hard-seededness, scored after a one-hour soaking (24). Plants were harvested promptly at maturity and after a two-week delay. The percent unimbibed seed after a one-hour soaking was highly correlated (r = 0.75**) with percent emergence. Only one of the 28 cultivars had a high percent unimbibed seed after a 24-hour soaking. This suggests one can identify lines with imbibition rates slow enough to provide protection against weathering without emergence problems associated with seed dormancy.

Kilen and Hartwig (26) studied the heritability of impermeable seed coats, assuming that the trait is controlled by maternal tissue. From the cross of Tracy x D67-5679 (impermeable seed), they found relatively few of the F_2 plants having as high a frequency of unimbibed seed as D67-5679 and concluded that at least three major genes control the permeability-impermeability characteristic. They outline a backcrossing procedure, assuming a three-gene model, to incorporate impermeability into an adapted, recurrent parent.

Heritability—Resistance to Field Weathering (Unspecified Mechanism)

Inheritance studies on components of resistance to field weathering have already been mentioned (26, 46). Green and Pinnell (13) evaluated inheritance of resistance to weathering, disregarding mechanisms of resistance. They crossed three cultivars of Japanese origin having resistance and the susceptible cultivars Chippewa and Harosoy 63. These authors assumed maternal plant control of resistance. Broad sense heritability estimates based on field emergence were very low, in part because of large variability in emergence among plants within the parents. Narrow sense heritability estimates also were low, ranging from 3 to 29 percent. Estimates of broad sense and narrow sense heritabilities also were very low for laboratory germination when hard seeds were included as normal seedlings.

Broad sense heritabilities for total normal seedlings in the laboratory germination test were low for crosses involving Chippewa because of high estimates of environmental variance, but, for crosses involving Harosoy 63, broad sense heritabilities ranged from

52 to 66 percent. Narrow sense heritabilities ranged from 18 to 60 percent for the Harosoy 63 crosses. Although these results are generally discouraging, the authors noted that a number of F_3 families from each cross gave field emergence values well within the range of the best parent and suggested that plants selected in the F_3 might be evaluated for resistance by testing bulked seeds of several F_4 progeny.

Green and Pinnell (14) also investigated heritability of visual seed quality characteristics from the same crosses mentioned above. Narrow sense heritability estimates were quite low for wrinkled seed coats, shriveled cotyledons, green cotyledons, average visual rating, and overall visual rating. This suggests that selection based on visual examination of seeds from F_2 plants will not predict with precision the visual quality of seeds from F_3 plants. Unfortunately parent-offspring regression was not carried out for F_4 on F_3 families. The authors did find quite high correlations between F_3 family visual quality ratings and field emergence. This would suggest that numerous F_3 families might be eliminated by visual observations, and emergence tests could be done only on those lines with apparent good quality. When Green et al. (12) further examined the relationship between visual scoring and field emergence, they reported much poorer correlations. This was probably because environmental conditions were less stressful, and, consequently, emergence scores were quite high, with small variances. Large experimental error values associated with field emergence measurements prompted the authors to recommend five-day laboratory germination counts in lieu of field emergence to estimate seed vigor.

TOLERANCE TO HIGH SOIL TEMPERATURE

Soil temperatures in the tropics frequently reach 40° C and above, and not all cultivars are able to emerge well at supra-optimal temperatures. Aquino and Bekindom (2) reported that the germination of Improved Pelican at 40° C was 28 percent, while that of cultivars LZ and Pennsoy was 16 and 11 percent, respectively. Unfortunately, no mention was made of how the seed of these cultivars was cared for prior to the test. Hatfield and Egli (17) found that neither Cutler nor Lee 68 germinated at 40° C. Emerson and Minor (10) evaluated the germination of 289 lines at 32° and 38° C and, from this initial screen, identified 48 accessions with apparent tolerance to high temperature. Tolerance to high temperature was greatly affected by the vigor of the seed. Lines from delayed harvest or lines that had been stored 15 to 18 months were very sensitive to high temperatures at germination. They found PI 259538, PI 346304, PI 374166, and PI 374174 were consistently among the most tolerant to high temperatures. It seems probable that too little attention has been given by plant breeders to this characteristic. Inheritance of heat tolerance needs to be determined.

CONCLUSION

Soybean production is not likely to expand in the tropics if farmers cannot consistently get good plant stands. Producing and maintaining good quality soybean seeds for planting is problematic. Fortunately, there are promising opportunities to develop cultivars less sensitive to the adverse conditions that frequently occur during maturation and storage in the tropics. Resistance has been identified to different pathogens involved in field weathering of seed, and it has been demonstrated that the slow-imbibition characteristic provides protection from the disruption of seed tissues that results from alternate wetting and drying as seeds mature under rainy conditions. Resistance to deterioration of seeds during storage also has been identified. It is now time for both national and international programs to explore these sources of resistance and provide cultivars better at meeting the needs of farmers in the tropics.

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DISCUSSION

S. Shanmugasundaram: Do the germplasm identified to have resistance to field weathering have a common origin? Is there only one source? Does this fact have any implications? Is resistance to field weathering associated with any undesirable characteristics?

E.A. Kueneman: Yes, I believe there are implications concerning the origins of many lines with resistance to field weathering; most resistant lines identified at IITA are from Indonesia. Soybeans evolved in the temporate regions but have been grown successfully for a very long time in Indonesia, which is located in a subtropical region with a rather adverse environment (warm and humid) for quality seed production. Indonesian farmers must have selected varieties resistant to weathering stress. Not all varieties from Indonesia, however, have high levels of resistance to weathering.

I know of no undesirable characteristics necessarily associated with resistance to field weathering, with the possible exception that, if the mechanism of resistance involves "extreme hardseededness," poor stands may result from the failure of seeds to imbibe water after sowing, unless seeds are scarified. The majority of our resistant materials are not extremely hardseeded, though some have one- or two-hour delays in water uptake.

F.C. Quebral: The papers presented this afternoon centered on the problems of seed damage due to mechanical equipment, insects and diseases, and deterioration in storage. I wonder if there have been any studies on storing soybeans in pods and if the variety is appropriate. The pods could shatter, which would solve the problem of mechanical damage due to threshing.

E.A. Kueneman: In a preliminary test, we did find that soybeans stored slightly better in the pod than when threshed; the difference was not great. There are several obvious problems in using shattering varieties. The plants would have to be removed from the field before the seeds reached a low moisture percentage, so some method of drying the seeds in the pod would be required.

M.D. Tedia: Were you able to simulate soil crust formation in your emergence test?

E.A. Kueneman: The ability of seedlings to penetrate crusted soils may be related to storability in that good seed vigor results in rapid emergence and escape from crusting. In that respect, seeds with good vigor seem to have a greater emergence force.

We have not yet developed a good screening method for identifying those lines with the greatest emergence force independent of seed vigor.

E. Pili-Sevilla: I have two questions: What do you mean by "pseudo-dormancy"? And has there been any work on the relationship of chemical composition, especially saturated fatty acid content, to storability?

E.A. Kueneman: Perhaps my choice of the term "psuedo-dormancy" was unfortunate. I was attempting to describe the situation in which the characteristic of hardseededness, when extreme, may result in nonuniform stand establishment. If some seeds germinate two weeks after sowing, weeds may become a problem due to the lack of competition, and the harvest may be difficult because of variable plant maturation.

We have not yet thoroughly investigated the relationship between seed storability and chemical composition. In a preliminary test we did not find a relationship between percentage of protein and inherent storability.

R.F. Gretzmacher: Please evaluate methanol stress-testing.

E.A. Kueneman: The methanol stress test for determining seed vigor as developed by scientists at the Boyce Thompson Institute involves soaking seed in 20-percent methanol (v/v) for two hours, followed by a water rinse. The effects of the stress can be monitored by laboratory germination tests, emergence tests, leachate conductivity, and so on. We found the methanol stress test to be related to accelerated aging, but it appears that a few genotypes that perform well under accelerated aging are very sensitive to methanol treatment.

Chin Ling Wang: Have you found any relationship between the coloration of soybean seed coats and their storability or their tolerance to high temperature and high humidity?

E.A. Kueneman: We have noted that a high percentage of the varieties identified as having resistance to field weathering and superior storability are brown- or black-seeded. However, not all blackseeded lines have good storability. Basic research should be initiated to determine the role of pigments and other products derived from pigment synthesis pathways in the maintenance of seed vigor.

P.S. Bhatnagar: Have you worked out the heritability of storability of soybeans? What precise reason is there, or what changes take place that are responsible for deterioration of seeds in storage?

E.A. Kueneman: As I mentioned, there is a maternal plant influence on the storability of seed. The phenotype of the seed (related to storability) is largely determined by the genotype of the mother plant producing the seed, so expression of genetic segregation is delayed for one generation. Studies to determine the narrow sense heritability by parent-offspring regression are well underway but have not been completed. We hope that we will soon be able to determine the relative effectiveness of selection at different generations.

The precise reasons for seed deterioration during storage are not well understood. Many biochemical changes occur at the onset of aging, and it has been difficult for physiologists to identify which changes are primary and which changes are secondary. One attractive hypothesis is that cells lose their membrane integrity, which would explain increases in conductivity of seed leachate and account for the broad change of biochemical changes that are observed as seeds lose vigor. Pathogens appear to play a more secondary role in deterioration of dry seeds during storage. Membrane disruption would allow pathogens to grow rapidly on exposed cell contents during the early stages of germination.

Seedborne Microorganisms and Viruses and Seed Quality

J.B. SINCLAIR

In the tropics and subtropics, producers have difficulty obtaining good quality soybean seeds for planting. A number of factors, many of which are discussed elsewhere in this publication, contribute to this problem. A major contributing factor to production of poor quality seeds is pathological; i.e., fungi and bacteria and viruses associated with soybean seeds. All soybean seeds are capable of carrying many kinds of microorganisms, including various fungi and bacteria and viruses, many of which can cause disease in soybean plants (11). Some of the important effects of these microorganisms are reductions in storage life, germination, emergence, vigor and eventually yields. The effect of microorganisms on soybean seeds in storage is discussed elsewhere in this publication.

Agronomists, plant breeders, physiologists, and pathologists often describe soybeen seed deterioration after a delayed harvest as "weathering." Weathering is usually a problem under warm moist conditions, and the characteristics of "weathered" seeds often are identical with symptoms caused by seedborne microorganisms (3). Breeding for improved soybean seed quality or "resistance to weathering" is breeding for tolerance to microorganisms (7).

Many of the most destructive pathogens of soybeans are seedborne. There are at least 66 fungi, 6 bacteria, and 8 viruses reported to be seedborne or associated with soybean seeds (10).

The role that various microorganisms play in reducing seed quality and the environmental factors affecting their expression have been defined only recently. There are many nonpathogenic and pathogenic microorganisms as well as plant viruses that are seedborne in soybeans (10). Among the most important fungal pathogens are *Phomopsis* spp. (*Diaporthe phaseolorum* var. *sojae*), which causes pod and stem blight and seed decay; *Colletotrichum dematium* var. *truncata*, which causes anthracnose and seed discoloration; *Cercospora kikuchii*, which causes purple seed stain and leaf spot and/or discoloration; and *Cercospora sojina*, which causes frogeye leaf and pod spot. In addition to these, *Fusarium* spp. play a significant role in soybean seed production in the tropics, but little is understood about their importance and the factors that affect their expression (5). Methods for detecting these and other pathogens associated with soybean seeds are presented elsewhere in this publication. A book on the sources of resistance to these and other soybean pathogens has been published (13).

A number of bacteria are seedborne (11). *Bacillus subtilis* can cause severe losses when seeds are planted in tropical and subtropical soils with high temperature and moisture levels (1, 8, 12). Several tropical countries, including Egypt, India, Indonesia, Ivory Coast, and The Philippines, report that it is difficult to obtain a stand of soybeans planted in soils with temperatures of 35°C or more. Indirect evidence suggests that *B. subtilis* is involved.

EFFECT OF FUNGAL PATHOGENS

Many of the microorganisms associated with soybean seeds are inside the seed coat, but some are found also outside the seed and between the seed coat and the embryo (9). Individual seeds in each seed population may vary among themselves in the type and number of microorganisms they carry.

Infection by *Phomopsis* spp. of soybeans grown in Illinois decreased the number of symptomatic seeds in a seed lot, reduced test weight, and increased the number of split seeds (Table 1). Oil and flour quality were reduced when high percentages of infected seeds were present (3). In a three-year study of seed decay of soybeans

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Table 1. Grade-related Components of Wells Soybean Seeds—with or without Symptoms of Phomopsis sojae *(after Hepperly and Sinclair, 1978 (3)*

Seedlot	Weight[a] (g)	Volume[a] (ml)	Density[a] (g/ml)	Splits[b] (%)
With symptoms	14.2	22.4	0.63	7.8**[c]
Without symptoms	16.7**[c]	25.2**[c]	6.6*[c]	1.4

[a]Means based on 12 replications of 100 seeds each.
[b]Mean number of split seed after simulated grain handling of 5 replications. Data were transformed using a square root transformation.
[c]The symbols ** and * indicate statistical significance $P = 0.01$ and 0.5, respectively, using FLSD test.

caused by *Phomopsis* spp. in Illinois, disease incidence was highest in 1977, lowest in 1976, and intermediate in 1975 (9). A low positive correlation was found between temperature and disease incidence, but no continuum of disease from north to south within the state was apparent. The highest incidence of *Phomopsis* seed decay occurred along major waterways in the wet years of 1975 and 1977. A high positive correlation was found between disease incidence and rainfall during pod fill, indicating that moisture, rather than temperature or geographic area, is the dominant environmental factor in disease development. Maturity dates of cultivars interacted with changing weather conditions to affect disease incidence. It was found that cultivars in maturity group II had the highest level of *Phomopsis* seed decay. Cultivars used in seed production in Illinois should be grown at latitudes where they will mature late in the season and escape conditions conducive to high incidence of seed decay.

A study was made on the effect of pod age and seed colonization by *P. sojae* (4). In this work pods with full-sized seeds, which were green to brown, were detached from greenhouse plants, surface-disinfected, and inoculated with *P. sojae*. After one week of incubation at 95 percent RH and 25° C, wound-inoculated Corsoy pods had increased frequencies of pod lesions and seed infection and reduced germination, in comparison with surface-inoculated pods. Stage of pod senescence was critical for rapid seed colonization. Low levels of seed infection were found in green Harosoy pods, whereas high levels were found in yellow and brown pods. Increasing the period of pod incubation increased the rate of seed infection, regardless of pod maturity. Lesions on green pods were centered about trichomes. Pubescent cultivars Corsoy, Hark, and Harosoy developed more pod lesions than the sparsely pubescent Chippewa. Disease assessment of inoculated intact plants and inoculated detached pods for Hark, Rampage, Wells, and Williams showed results from both methods were closely correlated, and cultivars Hark and Williams were less susceptible to *P. sojae* than Rampage and Wells.

Anthracnose is becoming an increasingly important disease in the tropical production areas (Arwooth NaLampang, Ministry of Agriculture, Bangkok, Thailand, 1980: personal communication). In a study completed in India, it was found that seeds harvested after the monsoon period were of higher quality and had a lower incidence of seedborne *C. dematium* var. *truncata* and other seedborne fungi than seeds harvested during the monsoon (6). This is similar to the results obtained with *Phomopsis* spp. (9). These results suggest that soybean seed fields should be in areas where dry conditions prevail during the maturation period of seeds. This may result in low yields of high quality seeds, but if seeds are harvested during a wet period, yields may be higher and seed quality lower.

The role of *Cercospora kikuchii*, the causal fungus of purple seed stain, in soybean health is poorly understood. There is a disagreement among pathologists as to whether *C. kikuchii* affects seed germination. However, in a study of seed lots varying in the number of purple-stained seeds, it was found that as the percentage of purple stain of the seed coat increased, there was a concomitant decrease in germination (14). A study was made to investigate the interactions between naturally occuring *C. kikuchii* and other seedborne fungi in soybeans, and their combined effects on germination of seeds produced in Puerto Rico and in Illinois (5). It was found that the predominant fungus recovered was *C. kikuchii* from seeds produced in Puerto Rico and *Phomopsis* spp. from seeds produced in Illinois, and that purple-stained seeds had higher germination at normal harvest than unstained seed. *Cercospora kikuchii* from Puerto Rico-grown seeds was antagonistic to seedborne *Fusarium* spp. and *Phomopsis* sp., which were recovered six and three times more often, respectively, from unstained than from purple-stained seeds. *Cercospora kikuchii* and *Phomopsis* sp. were not antagonistic in Illinois seeds except when incidence of *Cercospora kikuchii* exceeded 10 percent. Recoveries of *Fusarium* and *Phomopsis* increased, and germination and recoveries of *C. kikuchii* decreased when harvest was delayed in Puerto Rico. Multiple regression equations related the occurrence of *C. kikuchii*, *Fusarium*, and *Phomopsis* to reduced soybean seed germination in Puerto Rico. In Illinois, variation in the incidence of *Phomopsis* explained most of the variation in germination.

Frogeye leafspot, caused by *C. sojina*, is more common and potentially severe in the tropics and subtropics, where abundant rain and high humidity during the growing season makes the risk of epiphtytotics greater than in the drier temperate regions. In a study in which 29 soybean cultivars, ranging in maturity groups from 00 to IV, were inoculated with 10 isolates of *C. sojina* and the seeds collected in either of two ways: (1) from pods removed by hand from each of 16 cultivars or (2) from threshed seeds of each of 13 cultivars (15), paired comparisons were made among the percent defoliation and seed infection by *Cercospora kikuchii*, *Cercospora sojina*, and *Phomopsis* spp.; 100-seed weight, percent purple-stained seeds, percent soybean mosaic virus-mottled seeds, and germination. The recovery of *C. sojina* varied from 0 to 91.6 percent. There were correlations (P=0.0001) between defoliation, percent *C. sojina*, and a negative correlation for seed infected by *C. sojina* and *C. kikuchii*, *Phomopsis* spp. and percent purple-stained seeds for hand-harvested seeds; and for 100-seed weights and soybean mosaic virus-mottled seeds for both hand-harvested seeds and threshed seeds. The greatest reduction of 100-seed weights was due to *C. sojina*.

EFFECT OF VIRUS PATHOGENS

Of the eight viruses reported to be seedborne in soybeans, soybean mosaic virus (SMV), tobacco ringspot virus (TRSV), and tobacco streak virus (TSV) may be of economic importance (11). Similarly, seeds infected with TRSV or TSV would give rise to infected seedlings. The symptoms produced on seeds from infected soybean plants have been described elsewhere in this publication. Seeds infected with SMV may not germinate, or, if they do germinate, they produce diseased seedlings, which are unthrifty and do not compete well under field conditions.

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DISCUSSION

B.B. Singh: Dr. Sinclair, you have very nicely shown us different organisms that are carried by seeds. Some of these cause changes in seed appearance and can be easily distinguished. What should be our maximum limit of such diseased seeds in seed lots for them to be certified?

J.B. Sinclair: It depends upon the intended use of the seed, the nature of the seed-borne pathogen, and the occurrence of the pathogen in the country.

I. Kaliangile: Is purple stain of economic importance in your country? If so, what methods are used to reduce or avoid it, and what is your maximum acceptable percentage of seed affected by purple stain in seed lots?

J.B. Sinclair: It is of importance because some nations have quarantines against purple seed stain. There are no official standards affecting purple seed stain. Control is through the use of systemic fungicides or the use of date of planting standards.

Effects of Stinkbug Damage on Soybean Quality

JAMES W. TODD

Stinkbugs, primarily members of the insect family Pentatomidae, cause feeding damage to soybeans over much of the worldwide soybean production area. At least 40 species of stinkbugs have been found on soybeans, but damage has actually been documented for only a few species. There is at least one important stinkbug pest of soybeans in each major soybean producing region of the world (22). Among the species that have been reported to feed on soybeans are *Nezara viridula* (L.), *Acrosternum hilare* (Say), *A. acutum* (Dallas), *A. marginatum* (Palisot de Beauvois), (*Piezodorus guildinii* (Westwood), *P. pallescens* (Germar), *Thyanta pallidovirens accera* (Stal), *T. custator* (F.), *T. perditor* (F.), *Edessa meditabunda* (F.), *Euschistus servus* (Say), *E. tristigmus* (Say), *E. obscurus* (Palisot de Beauvois), *E. quadrator* Rolston, *E. ictericus* (L.), *E. heros* (F.), *E. crenator* (F.), and *E. variolarius* (Palisot de Beauvois). The most important and cosmopolitan pentatomid pest of soybeans is *N. viridula,* commonly known as the southern green stinkbug. Numerous records of *N. viridula* have been published from throughout the tropical and subtropical regions of Europe, Asia, Africa, and the Americas as well as the islands of Oceania (3, 14, 27).

The following discussion deals primarily with *N. viridula,* with additional comments on *A. hilare, E. servus,* and *P. guildinii,* which are other species known to be of widespread importance in soybeans.

STINKBUG POPULATION DYNAMICS AND NATURE OF DAMAGE

All stinkbug species have five nymphal instars or immature stages. First stage nymphs congregate on or near the egg mass and have not been observed to feed while aggregated. However, just before or subsequent to molting, nymphs become active, disperse more or less, and begin to feed. Nymphs, like adults, usually inhabit those portions of plants upon which they prefer to feed, the tender growing shoots or more importantly the developing fruit or seed. During the summer, development from egg to adult takes about 35 to 37 days, with temperature having an important bearing upon this (7, 8, 11). Many stinkbug species are highly polyphagous, attacking both monocots and dicots (9, 22). My own observations and those recorded by various authors in the literature indicate that *N. viridula* has a distinct preference for a few species of plants, particularly some of the legumes. This preference varies with the development and phenology of the preferred host plants in the different seasons of the year. The strongest expression of preference is during fruit or seed formation, after which the senescing plants become unattractive, and the bugs move on to more succulent hosts.

Synchronization of host plant and pest phenologies is an extremely important consideration in the characterization of pest populations. This is particularly important with respect to members of the stinkbug complex on soybeans since most species are primarily pod or seed feeders and population peaks must, therefore, coincide with the seed developmental stages of the primary host species. Although a few individuals can be found in the crop throughout the growing season, soybeans are attractive to stinkbugs primarily after flowering and podset in late July and August. The phenological relationship between growth stages of soybean plants and stinkbug populations is illustrated (Fig. 1).

The mouthparts of stinkbugs (as in all Hemiptera) are modified for piercing and sucking. Both nymphs and adults obtain their food by puncturing the tissues of plants with their stylets, injecting powerful digestive enzymes, and extracting the plant juices. Feeding punctures caused by the insertion of the rostrum form

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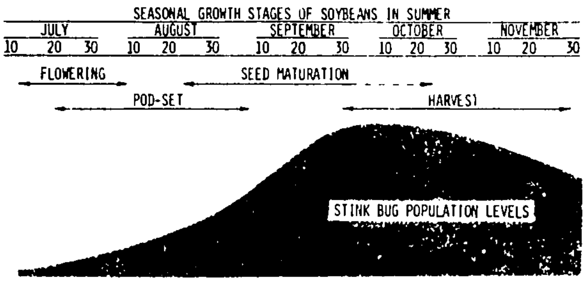

Figure 1. Stinkbug populations during soybean flowering and seed maturation.

minute, hard, brownish or blackish spots on the plant. The nature and extent of stinkbug damage to soybeans depend upon the stage of seed development at which feeding occurs. Feeding by stinkbugs during the early stage of seed formation can result in shriveled, deformed, and undersized seeds. Feeding during later stages of endosperm development results in a sunken, deformed area beneath the puncture marks where the stylets have pierced the seed coat. The flesh of the damaged cotyledons is characterized by whitish chalky areas where the cell contents have been removed. Frequently, a dark discoloration may be present around the punctured area, and the inner membrane of the seed coat may be fused to the cotyledons (2, 5, 13, 17, 26).

Besides the physical manifestations of damage inflicted during the feeding process, several other qualitative aspects of damage are evident.

Soybean seeds damaged by stinkbugs have a slightly higher protein content than nondamaged beans (16, 17). Qualitative changes in soybean oil also are observed as the severity of stinkbug damage increases; linoleic, palmitic, stearic, and oleic acids increase while linolenic decreases (25).

Germinability, emergence and seedling vigor are also reduced by seed damage resulting from heavy infestations of stinkbugs during seed maturation. Daugherty et al. (5) found that, following heavy infestation of *E. servus*, germination was reduced in relation to the number of feeding punctures per soybean seed. Conversely, Jensen and Newsom (10) showed that, with regard to viability, location of a stinkbug puncture is probably more important than the number of punctures. These authors stated that one puncture in the radicle-hypocotyl axis of the seed could prevent germination, whereas several punctures in the cotyledons may affect vigor of the plant but not prevent germination.

A quick and easy germination test, the tetrazolium test (TZ), is available for identifying nonliving areas of soybean seeds (6, 18). This test is applicable for evaluation of stinkbug-damaged soybean seed for germinability. Although it has not been widely utilized, this test (TZ) provides a good tool for detailed research on location and effects of stinkbug punctures on seed viability. We tested emergence and seedling survival of soybean plants grown from seeds exhibiting each of the various degrees (or categories) of damage described below:

1. Light injury--seed with puncture marks but no deformity of the seed coat or endosperm;
2. Medium injury--seed with puncture marks and mild deformity but no reduction in size;
3. Heavy injury--seed with puncture marks, gross deformity, and some reduction in size and weight; and
4. Severe injury--seed with puncture marks, gross deformity, and drastically reduced size and weight.

The last two categories sometimes are combined into one category called "heavy" or "severe." Soybeans in these categories are of no value for oil, meal, or seed.

The results of this test are summarized (Table 1). There were significant reductions in emergence of seed with light stinkbug damage on all observation dates when compared with seeds with no stinkbug damage. Emergence and seedling survival from seeds with medium, heavy, or severe damage were significantly reduced in comparison with emergence and survival of seeds with no damage or with light damage.

Miner (17) compared the damage to soybeans by the green, the southern green, and the brown stinkbugs in field cages. He found that the type and severity of damage done by the green stinkbug was identical to the damage done by the southern green stinkbug. He reported also that the brown stinkbug similarly caged caused much less damage than the southern green stinkbug. McPherson et al. (15) reported similar results, except that their work revealed that late instar nymphs and adults of *E. servus* produced damage comparable to that of *N. viridula* and *A. hilare* when population densities were maintained at high levels.

Todd and Turnipseed (23) reported significant reductions in seed yield and significant increases in seed damage from population densities of 3.3, 9.8, and 16.4/row-m. They further reported that seeds harvested from cages containing 40 pods infested on four dates with a single bug (fourth instar

Table 1. Mean Percentage Emergence and Seedling Survival of Soybean Seeds Exhibiting Various Degrees of Damage by Nezara viridula*, 1970, Tifton, Georgia*

Seed damage category	$\bar{X}$ Percentage of emergence on following dates[a]			Percentage of live seedlings[a]
	1/23	1/29	2/5	2/16
No damage	70.0 c	80.5 e	86.5 d	84.5 c
Light	53.5 b	63.8 d	69.5 c	65.8 b
Medium	10.3 a	11.0 c	14.5 b	7.8 a
Heavy	3.5 a	2.0 b	3.8 a	1.0 a
Severe	0.0 a	0.0 a	0.0 a	0.0 a

[a]Means followed by the same letter do not differ significantly at the 5 percent level by Duncan's Multiple Range Test.

through adult) exhibited 63.9 to 78.5 percent damage. Yeargan (28) reported similar results with caged populations of *A. hilare* in Kentucky. McPherson et al. (15) reported significant yield reductions in small field plots when a population of 1.8 bugs/row-m (primarily *N. viridula*) was maintained for a six-week period during the pod-filling stage of crop growth. These results indicate the potential of this pest complex to inflict serious damage on soybeans in the field.

Stinkbug damage not only affects soybeans directly through reduction in yield and quality but also indirectly by providing an entry point for the introduction of disease organisms, such as the yeast spot disease, *Nematospora coryli* Peglion. Kilpatrick and Hartwig (13) reported isolations of a number of fungi from stinkbug-injured and nonpunctured seeds. Their data indicated, however, that stinkbug injury was not necessary for fungal infection. In tests by Daugherty (4), six species of pentatomids were capable of transmitting *N. coryli* into developing soybean seeds. Ragsdale et al. (20) isolated several bacterial genera from organs of the southern green stinkbug and subsequently showed insect transmissibility of five bacteria pathogenic to soybeans. Panizzi et al. (19) reported a similar insect/pathogen relationship with *P. guildinii*. Over 30 percent of the injured seeds were infested with *Fusarium* sp., while other important pathogens isolated included species of *Phomopsis*, *Diaporthe*, *Colletotrichum*, *Cercospora*, *Rhizoctonia*, and *Macrophomina*.

Research in Puerto Rico (12) showed that *N. viridula* might be involved in the transmission of bacterial blight (*Xanthomonas* sp.) in beans. The authors often collected *N. viridula* from bacterial blight-infested bean plantings, and infection of plants also resulted when *N. viridula* was artificially infested with bacterial isolates and then allowed to feed on bean leaves.

Another potential trouble spot arises when stinkbug-damaged soybeans are placed in storage. Certain stored-product insects have indicated a strong preference for stinkbug-damaged soybeans over nondamaged soybeans. On soybeans with various degrees of stinkbug damage, cigarette beetle (*Lasioderma serricorne*) damage increased proportionately to the degree of stinkbug damage. In experiments at Tifton, nonstinkbug-damaged beans were left completely free from beetle damage, while the most severely damaged group was destroyed completely. The beetles then attacked the next group of beans with lesser degrees of damage until all groups were infested. The most important implication of this is that soybeans containing an appreciable amount of stinkbug damage may be subject to attack by this stored-product insect and possibly others; whereas, sound seed without stinkbug damage may not be attacked (24).

STINKBUG CONTROL AND ECONOMIC CONSIDERATIONS

Süber and Todd (21) reported that a variable treatment threshold based on crop phenology is recommended for the initiation of chemical control measures for stinkbugs in Georgia. Control is recommended when populations exceed 1.1 bugs/row-m up to mid-pod-fill. From mid-pod-fill through maturity, control measures should be initiated when populations exceed 3.3 bugs/row-m. However, where the crop is produced for seed, 1.1 bugs/2 row-m are sufficient to justify control. Many soybean-producing states where stinkbugs are annual pests now employ similar thresholds.

States differ in the handling of stinkbug-damaged seeds at the market. Discounts are made at the purchase point based primarily upon the extent of stinkbug damage routinely encountered in seed lots. The United States National Grain Standards (1) state that seed lots should be docked for stinkbug damage on the basis of one-fourth of the actual damage present. Buyers in some countries follow this procedure, and others disregard stinkbug damage completely. Still another group assesses stinkbug damage along with all other types of damage, thereby basing the discount on the actual percentage of stinkbug-damaged seed. This factor bears directly on economic thresholds and should be considered when they are implemented.

OUTLOOK AND NEEDS

Stinkbugs are cosmopolitan species that have readily adapted to soybeans. Their host range is so vast that it allows them to inhabit a variety of seasonally attractive plants and inhabit a given area year-round. Furthermore, they display special physiological adaptations for reproduction and diapause, and their behavior may involve sound communication, as well as pheromone systems (22).

The needs for management of this complex are obvious:

1. Refinement of economic thresholds for the various species and coexisting guilds of stinkbugs. In areas where fungal diseases are transmitted by stinkbugs, thresholds should be developed in consideration of both puncture damage and accompanying damage by the fungus. This relationship may lower the level of economic tolerance to stinkbug damage.
2. Improvement of sampling methods, including sequential sampling plans for each species and the various guilds. Trends in population density of various stinkbug species must be related to seed yield and quality.
3. Studies relating plant and pest phenologies (by cultivar if possible) to damage, and development of trap crop systems of early fruiting soybean cultivars.
4. Ecological studies to determine the role of vegetational diversity and weed and disease control measures on stinkbug densities are also needed.
5. Studies to evaluate the impact of natural control factors and to find ways to enhance their effectiveness.
6. Development of descriptive models and information retrieval systems.
7. Development of resistant host plants (soybean cultivars as well as other hosts).
8. Studies to develop ecologically sound chemical control tactics for use during damaging population outbreaks.

Since stinkbug damage to soybeans directly affects two of the most critical seed quality problems, germinability and seedling vigor, every effort should be made to determine whether a "stinkbug problem" exists in a given area. If outbreak situations occur, management systems should be designed to incorporate all applicable control tactics to keep populations below the economic thresholds.

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DISCUSSION

B.K. Divetia: In one of the slides you showed that, with the increase of stinkbug damage, the linoleic and linolenic acid content goes down. This may be good from the standpoint of extending shelf life and retarding rancidity development in soybean oil, but how does it affect general yield of oil and protein and their characteristics?

James W. Todd: With the increasing severity of stinkbug damage, there is generally a relative increase in total protein and a decrease in total oil content of the seed.

B.B. Singh: What was the overall total damage in your seed samples where fatty acid composition was tested?

James W. Todd: Overall damage irrespective of extent of damage ranged up to about 75 percent.

V.K. Agarwal: Stinkbugs have been shown to cause biochemical changes and also to help in the invasion of fungi into the seed. What was the basis for saying that the biochemical changes were the result of stinkbug damage and not due to the presence of storage fungi?

James W. Todd: We did not investigate the presence of fungi or other microorganisms in these studies. There is a critical need for this to be done.

Paul Hepperly: What are the environmental (temperature and moisture) effects on stinkbug biology, population development, and losses? Are there gaps in our knowledge in this area?

James W. Todd: Generally, germination time is shortened in higher temperatures. Relative humidity also has an important bearing on life cycles and population dynamics. High RH and precipitation in large amounts over extended periods of time appear to have an adverse effect on the insect's biology. We do have gaps in our knowledge of this.

Rose Amanda Lovera: How did you know that the grain damage that you saw was produced by bugs? We have the same problem in the September rainy season. Why not in the dry season?

James W. Todd: This was determined through experimentation with artificially infested caged soybeans and direct observation. We have not observed this relationship at Tifton, Georgia.

Soybean Seed Quality and Practical Storage

B. R. GREGG

A major constraint to expansion of tropical soybean production is lack of adequate planting seed. Soybean seeds are physiologically mature at peak germination and vigor when they reach their maximum dry weight of 40 to 50 percent moisture content, about 65 to 75 days after flowering (1). However, germination is often too low for economic use as seed when farmers are ready to plant.

Soybean seeds normally must be stored for up to a few months before they are planted. After seeds first reach physiological maturity, deterioration or aging commences and moves inexorably toward death. Once deterioration has begun, it cannot be eliminated. Storage cannot stop deterioration, but it can minimize it to maintain germination until planting.

LITERATURE REVIEW

Longevity of Soybean Seed in Storage

Soybean seeds inherently have a short life span. Justice and Bass (11) classify soybeans in the "least storable" group in their "Relative Storability Index." In the southeastern United States (8), germination is barely maintained for seven to nine months in ambient storage following harvest. In tropical areas, such as Thailand, seed viability often is lost within two to three months after harvest.

Soybean seeds cannot withstand ambient tropical storage conditions of high temperature and seed moisture but can store well at controlled low temperatures and/or moisture contents. Toole and Toole (11) stored 13.5 percent moisture soybean seeds at 2° C and -10° C for ten years and maintained full initial viability for ten years at 10° C.

Causes of Deterioration

Soybean seeds deteriorate rapidly. Any condition that affects the seed influences its storability, including:

1. *PREHARVEST FIELD CONDITIONS*. Soybean seeds deteriorate significantly between maturity and harvest (3, 4, 7) due to high humidity, high temperatures, and alternate wetting and drying due to rain. Hot, dry weather and inadequate soil moisture during seed maturation also cause low seed quality, like the green seed problem in Thailand.

2. *MATURITY AT HARVEST*. Immature seeds--which can be characterized as being smaller than normal size, shriveled, light in weight and/or having wrinkled seed coats, immature green color, and so on--do not store well (11).

3. *HIGH MOISTURE*. The single most damaging influence is high moisture. Seeds must be dried to safe moisture levels immediately after harvest and held at a safe moisture content level until planted. As moisture increases, seed deterioration increases. Harrington's rule of thumb states that for seed of 5 to 14 percent moisture, each 1 percent reduction in moisture approximately doubles seed storage life (11).

High-moisture seeds deteriorate faster and are more susceptible to damage from extreme temperatures, fumigation, treatment, storage fungi, pathogens, insects, heating, and mechanical injury (4, 10, 11). Traditional harvesting and drying in most tropical countries do not reduce seed moisture adequately and rapidly enough and cause much seed deterioration (7).

High relative humidity (RH) also affects seed moisture. Seeds are hygroscopic and absorb moisture from the humidity or invisible

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water vapor in the air at high RH and lose moisture to the air at low RH. Exchange with the air affects seed moisture until it reaches equilibrium. The following equilibrium moisture contents of soybean seeds have been reported (8):

Relative humidity (%)	Seed moisture equilibrium (%)
15	4.3
30	6.5
45	7.4
60	9.3
65	11.0
75	13.1
80	16.0
90	18.8

4. *HIGH TEMPERATURE.* High temperature ranks close to high moisture as a deteriorative influence. Harrington's rule of thumb on temperature states that from 0° to 50° C, each 5° C increase in storage temperature halves the seed's life span (11). High-moisture seeds are more susceptible to damage from high temperatures. Both constant and short exposures to high temperatures cause deterioration (11).

5. *MOISTURE-TEMPERATURE INTERACTION.* Seeds of higher moisture content can be stored at lower temperatures; low-moisture seeds store longer at higher temperatures. Combined high moisture and high temperature cause rapid seed deterioration (6, 11).

6. *MECHANICAL INJURY.* Seeds with mechanical injury deteriorate faster and are more susceptible to storage fungi and treatment damage (11). A damaged seedcoat permits exposure to air and accelerates oxidation of lipids (13).

7. *SEED TREATMENT.* Seeds of high moisture, with mechanical damage, or stored for extended periods may be adversely affected by some treatments. Excessive treatment rates also may reduce storability (11).

8. *STORAGE FUNGI AND DISEASE ORGANISMS. Aspergillus* and *Penicillium* occur widely and may attack stored soybean seed of above 9 percent moisture (11, 16). *B. subtilis* is seedborne in soybean and reduces storability (9, 13, 14, 15, 16). Pod and stem blight (*Phomopsis sojae*) is seedborne and reduces storability. Some so-called weathering may be due to *Phomopsis* (13).

9. *INSECTS.* Storage insects may cause serious damage to seed stored at 9 percent or higher moisture content (11).

10. *PESTS.* Rats, mice, and birds eat seeds, damage bags, and scatter, mix, and contaminate seeds (10).

11. *FUMIGATION.* Some fumigants affect seed viability. Increased seed moisture, temperature, dosage, and exposure increase risk of damage (11).

PRESENT SITUATION

Storage

Seeds are stored from the time they mature until they are planted. They are stored (1) in the field and on the farm; (2) at the processing plant; and (3) during the period between processing and planting.

From maturation to harvest, seeds are stored in the field. Then, in small-scale agriculture, they are stored on the farm from harvest to threshing. They continue to be stored on the farm after threshing until they are delivered to the processing plant. Seeds are stored at the processing plant as they are received, dried, and processed. After they are processed, they are stored while in transport to the area where they are to be used. Such storage may be in retail outlets, en route to farmers, or on the farm before planting.

Seed may deteriorate from unfavorable conditions during any of these phases; all must be managed to ensure that seeds store well and reach the farmer with acceptable quality.

If seeds are harvested, dried, and handled to produce high quality, low moisture-temperature conditions can maintain viability with minimal decline during the nine-month storage period, which is adequate for most commercial soybean seeds in tropical areas (Table 1). Low seed moisture and lower-than-ambient temperatures are necessary.

Soybean seeds of high initial quality can be safely stored under tropical conditions for nine months at moisture contents of 9.0 to 9.5 percent (50 to 60 percent RH) and temperatures of 20° to 25° C.

For eight to nine months' storage, Delouche (6) recommends that (after harvest) soybean seeds be conditioned rapidly and properly, as follows:

1. To 12 to 13 percent moisture in temperate climates and stored in a dry, ventilated warehouse;
2. To 9.3 percent moisture (60 percent RH) or less in tropical and subtropical climates and stored in conditioned storage facilities at 20° to 25° C or less; or

Table 1. Recommended Storage of Soybean Seeds

Seed moisture	Storage temperature and conditions	Recommended For	Reference
10 to 12	Temperate climate ambient	8 to 9 months	8
9.3 or less	20° to 22° C in tropical and subtropical climates	8 to 9 months	8
In equilibrium with 50% RH	65° F. (18.3° C)	Carryover of high-quality seeds	5
6 to 7	Not over 35° C	Sealed vaporproof containers	11
Not more than 8	30° C and 50% RH	Short-term storage of oil seed	7
Not more than 9	20° C and 50% RH	Short-term storage of oil seed	7

3. To 9 percent or less moisture in tropical and subtropical climates and sealed in vaporproof packages, such as heat-sealed 10-mil polyethylene bags.

Cold seeds brought into a hot, high-humidity environment absorb moisture from the air and lose viability rapidly. This may be avoided by warming seeds to ambient temperatures in a dehumidified room before taking them into the outside air or by sealing seed in vaporproof packages.

Providing Safe Storage

SHORTER STORAGE PERIODS. Many tropical areas have a dry season and a rainy season; soybean seeds can be produced in one season for planting in the following one, and the storage period reduced to one to three months. High-quality soybean seeds properly dried and handled should then be storable in good, cool, dry, ambient storage environments. Dry-season production requires irrigation; facilities must permit immediate distribution.

VAPORPROOF PACKAGES. The vaporproof package has great promise for tropical areas. Immediately after harvest, seeds are dried to very low moisture content, processed, and sealed in vaporproof packages such as 10-mil polyethylene bags. Moisture vapor in the outside air cannot penetrate the bags, so seeds maintain their initial low moisture content.

Low-moisture seeds withstand higher temperatures, so less investment in storage structures and cooling equipment is required, and seeds are protected during transit and on the farm. Since seed moisture determines RH inside the bag, soybean seeds in sealed vaporproof bags must be dried to 6 percent (10) or 9 percent (6). Drying cost is increased. Seed bags must be handled carefully to avoid mechanical damage to very dry and susceptible seed, and soil moisture should not be excessive at planting. However, seed viability can be maintained effectively.

BULK STORAGE. Since soybean seeds are short-lived and sensitive to adverse tropical conditions, they require special storage conditions. To store soybean seeds in bulk, both before and after processing, would be more economical and efficient, and could avoid bagging losses and bag-handling costs if seed is not sold or loses viability.

In temperate climates, soybean seeds are stored in bulk in metal drying-aerating bins for a few weeks to as much as 6 months until they are processed. Seeds are dried to less than 13 percent moisture immediately after harvest (5, 6). Drying temperature should not exceed 38° C. Air flow should be 3 to 6 CFM per bushel (6, 8). Drying air RH should be above 40 percent, and drying bed depth should not be more than 90 cm (8).

Aeration in temperate climates is usually adequate for seeds at 13 percent or less moisture, at air flows of 0.1 to 1.0 CFM per bushel, with RH not more than 65 to 70 percent. Air flow of 1.0 CFM per bushel can reduce moisture by 1.0 to 1.5 percent (5, 6).

In tropical climates, bulk storage may cause drastic reductions in germination if seeds are not properly dried and aerated to maintain uniformly low moisture (6). Bulk bin storage of seeds is safe only if drying and aeration are integral parts of the system. Disastrous experiences have resulted from a lack of proper drying and aeration. Variations in ambient temperature cause variations in temperature within the stored seed mass and result in air convection currents. Moisture moves with warm air until it cools, at which point RH increases and seeds absorb moisture. This creates spots of high moisture, which destroy seed germination and create additional heat and moisture to spread deterioration through the seed mass.

This can be prevented by adequate aeration (6). However, aeration does not reduce seed temperature below the ambient temperature, nor can it reduce seed moisture below equilibrium with ambient RH. In tropical climates, ambient conditions often are not adequate for safe soybean seed storage for the required periods. Conditioned storage of low temperature and humidity are required to store even bagged seeds for the necessary time (17).

It would be difficult and expensive to maintain bulk storage bins at the lower-than-ambient temperature and RH required to store seeds for up to nine months. However, some form of safe bulk storage until seeds are distributed to farmers appears to be feasible, to avoid bagging expenses if the seeds are not sold.

Developed seed industries use bulk toteboxes and flexible bulk containers. These hold one to two tons of bulk seed and are handled by forklift and/or crane. Toteboxes are on pallet bases so they can be handled by forklift. Some flexible bulk (sometimes called semibulk) containers are mounted on pallets and handled by forklift. Others are palletless and are lifted and moved by straps or cords attached to the tops.

At relatively moderate increases in construction costs, conditioned storerooms can be equipped with doors (and antechambers) adequate for a forklift to enter carrying a bulk container. The uniformly low temperatures and relative humidity in conditioned storerooms should maintain viability of soybean seeds in bulk containers; a uniform cooler temperature should eliminate convection moisture movement. This could considerably reduce both handling costs and seed losses over the long term (Table 2).

Table 2. Storage Conditions that Maintained Soybean Seed Viability for Nine Months with Not More than Moderate Drops in Germination

Seed moisture	Storage temperature and conditions	Packing	Reference
18.1	10°, 2°, -10° C		11
13.4	20°, 10°, 2°, -10° C		11
9.4	30°, 20°, 10°, 2°, -10° C		11
17.9	10°, 2°, -10° C		11
8.1	30°, 20°, 10°, 2°, -10° C		11
8	Oregon ambient "moderate"	Sealed, moistureproof bags	11
10.4	Mississippi ambient warehouse	3-ply, multiwall paper with 2-mil polyethylene liner	8
9	Indiana ambient warehouse	Multiwall paper or 7-mil polyethylene	8
8.6 D.B.	Puerto Rico ambient	Sealed metal can or metal can with 1-mil plastic liner	12
7	Puerto Rico ambient	Insulated with 15 cm rice hulls: Sealed tin can, unsealed tin can with 1-mil plastic liner, and jute bag with 1-mil plastic liner Not insulated: Unsealed tin can with 1-mil plastic liner and jute bag with 1-mil plastic liner	12
7.2	6° C and 30% RH	Multiwall paper and multiwall paper with 2-mil polyethylene	2
10.2	6° C and 30% RH	Multiwall paper and multiwall paper with 2-mil polyethylene	2
12.8	6° C and 30% RH	Multiwall paper with 2-mil polyethylene	2

RESOLVING PRODUCTION CONSTRAINTS

To ensure seed to support expanded production, soybean crop economics and seed technology must make it possible to achieve low seed moisture and low storage temperature as soon as possible after seeds mature and to maintain these conditions until seeds are planted.

Safe storage is possible with seed technology, facilities, and management according to seed requirements rather than according to local farmer technology. Soybeans are a prime example of the necessity for a high level of seed technology to serve a low-technology agriculture.

Packaging low-moisture seed in sealed, vaporproof bags, producing seed in "off-seasons" to shorten the storage period, and conditioned storage in bulk containers offer solutions to the constraining shortage of quality seed in tropical and subtropical areas. Research is needed under tropical conditions to identify suitable storage conditions and facilities, packaging, bulk containers, handling methods, commercial operating systems, and seed conditions to store seed safely for the required six to nine months. Research should be planned and coordinated to generate specific recommended facilities and procedures.

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Physiological Changes During Storage That Affect Soybean Seed Quality

JAMES C. DELOUCHE

The physiological changes in seed that lead to loss of viability are termed *deterioration*. Deterioration of seed has been defined as "an irreversible degenerative change in the quality of a seed after it has reached its maximum quality level" (2). It is an inexorable, irreversible process that progressively impairs the capabilities and performance of the seed and culminates in its death or—in practical terms—in loss of the germinative capacity (19, 20, 27).

Deterioration is traditionally associated with storage. In seed program/industry operations, however, storage is most often perceived as commencing with placement of packaged seed in a warehouse and ending with distribution. Packaged seed in a warehouse represents only one segment of the total storage period for seed, which begins at harvest and terminates at the time the seeds are planted (21,30).

Deterioration of seed is usually initiated during the period following physiological maturity while the seeds continue to dry down to the harvest maturity stage (22, 25, 54). This postmaturation, preharvest period is considered by some (19) to be the first segment of the storage period. The extent and severity of field deterioration of seeds (i.e., weathering) establishes their basic quality. During harvest and subsequent operations, quality can be maintained, but it cannot be improved—save in exceptional circumstances—over the level at harvest. The first task in seed storage, therefore, is to take all the steps necessary to ensure that the quality of harvested seed be as high as possible. The losses in seed quality caused by field deterioration and weathering and the operative environmental factors are discussed by Andrews (8) in a paper in this volume.

Field deterioration of seed in terms of causes and effects is essentially the same as deterioration after harvest. In this paper, therefore, deterioration is treated as a continuum of detrimental changes that can commence shortly after the physiological maturity stage is attained and continue until the germinative capacity is lost.

FACTORS AFFECTING THE RATE OF DETERIORATION

Deterioration of seed—as for all living systems—is considered to be inexorable. Theoretically, it cannot be prevented, but, practically, the rate of deterioration can be controlled so that viability is maintained for many years. This can be accomplished through control of the factors that affect the rate of deterioration.

The primary factors that influence the rate of deterioration of seeds are inheritance, temperature, and seed moisture content (28, 29, 32, 35). Other factors that influence the rate of seed deterioration through interaction with temperature and seed moisture content are relative humidity, the incidence and severity of mechanical damage, storage molds, and insects.

Inheritance

Soybean seeds are inherently short-lived (28). They deteriorate more rapidly than seed of rice, corn, sorghum, wheat, and many other seed kinds under the same conditions of production, harvesting, drying, and storage (Table 1). Of the major agronomic crops only shelled peanut seeds are more short-lived than soybean seeds.

The higher relative rate of deterioration of soybean seeds—as compared with other seed kinds—makes it very difficult to produce high quality seeds in the humid subtropics and tropics and even in the warmer areas of the temperate zone. Indeed, the difficulty in maintaining the viability of soybean seeds from harvest to the next planting season is one of the major impediments to extension of soybean production into the subtropics and tropics (23, 24).

Substantial evidence is available that the inherent short-livedness of soybean seeds is more characteristic of "modern" cultivars than of the species as a whole. There is

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Table 1. Germination Percentages of High Quality Seed Lots of Nine Species During Storage under Ambient Conditions at Mississippi State, Mississippi

Kind	Storage period (months)					
	0	6	12	18	24	30
Bean, snap	98	96	96	90	92	90
Corn, field	98	98	96	96	90	85
Cotton	95	93	95	92	90	84
Peanut, shelled	96	93	60	5	0	0
Rice	94	92	94	93	90	88
Sorghum	96	96	93	86	82	78
Soybean	96	94	85	60	42	0
Watermelon	98	98	96	95	90	88
Wheat	98	97	97	96	92	90

considerable variation in seed longevity within the species. Seeds of the cultivars grown in the United States during the period 1930-50 for forage stored quite well. The natural protection in the species against one of the primary factors influencing rate of seed deterioration, i.e., moisture content, is dormancy, specifically, hardseededness or impermeability of the seed coat to liquid or hygroscopic moisture (46, 47). Kueneman reports on his work on identifying differences in quality and storability of soybean seeds among genotypes in a paper in this volume.

There are also differences among modern cultivars in resistance to deterioration during weathering. Mohd-Lassim (39) demonstrated that seeds of the "Mack" cultivar deteriorated much more rapidly in the field than those of the "Dare" and "Forrest" cultivars that matured at the same time and were exposed to the same weathering stresses (Fig. 1). His findings corroborated the experience of seed producers that good quality seeds of the "Mack" cultivar are difficult to produce and store.

Temperature and Moisture Content

The primary roles of temperature and moisture content in deterioration of seed have long been established and are well documented (10, 17, 19, 28, 30, 33, 35, 42). Generally, the rate of deterioration increases as moisture content and temperature increase. Harrington's (32) "rules-of-thumb" for seed storage dramatize the importance of moisture content and temperature in maintenance of seed viability: the storage life of seeds is doubled for each 10° F decrease in temperature; the storage life of seeds is doubled for each 1 percent decrease in moisture content. The classic study of Toole and Toole (56) illustrates very well the effects of temperature and moisture content on the longevity of soybean seeds in storage, although the data are somewhat in variance with Harrington's "rules-of-thumb." Germination of 9.4 percent moisture seed was maintained for more than 10 years at 10° C, 5 years at 20° C, and only 1 year at 30° C. In contrast, germination of 13.9 percent moisture seed decreased below 80 percent within 5 years at 10° C, 2 years at 20° C, and 0.5 years at 30° C (Table 2).

In a more recent study, Andrews (7) demonstrated the importance of seed moisture content and temperature in "carry-over" storage of soybean seeds. Seed packaged at 10.4 percent moisture or less in multiwall three-ply paper bags with 2-mil polyethylene liners to retard moisture vapor transmission maintained germination above 80 percent for 18 months in Mississippi.

Seeds are hygroscopic. They absorb moisture from the atmosphere or lose moisture to it until the vapor pressures of seed moisture and atmospheric moisture come into equilibrium. Since the vapor pressure of atmospheric moisture at a specific temperature and pressure is a direct function of the degree of saturation or relative humidity, the different kinds of seeds attain specific or characteristic moisture contents when exposed to different levels of atmospheric relative humidity for a week or longer. The seed moisture content attained under these conditions is variously referred to as the equilibrium moisture content (EMC) or hygroscopic equilibrium value (28, 35). The EMC varies among seed kinds in relation to chemical composition. It decreases as oil content of the seeds increases (21). For all kinds of seeds the EMC also slowly decreases as temperature increases. The EMCs of soybean seeds at various levels of relative humidity at 25° C are:

Relative humidity (%)	Seed moisture equilibrium (%)
15	4.3
30	6.5
45	7.4
60	9.3
75	13.1
90	18.8

Since seed moisture content and ambient relative humidity are in equilibrium during storage, maintenance of a safe moisture content requires an average level of relative humidity in the storage environment no higher than that in equilibrium with the desired seed moisture content. This favorable situation can be achieved in only three ways (28): (1) storage in a region where relative

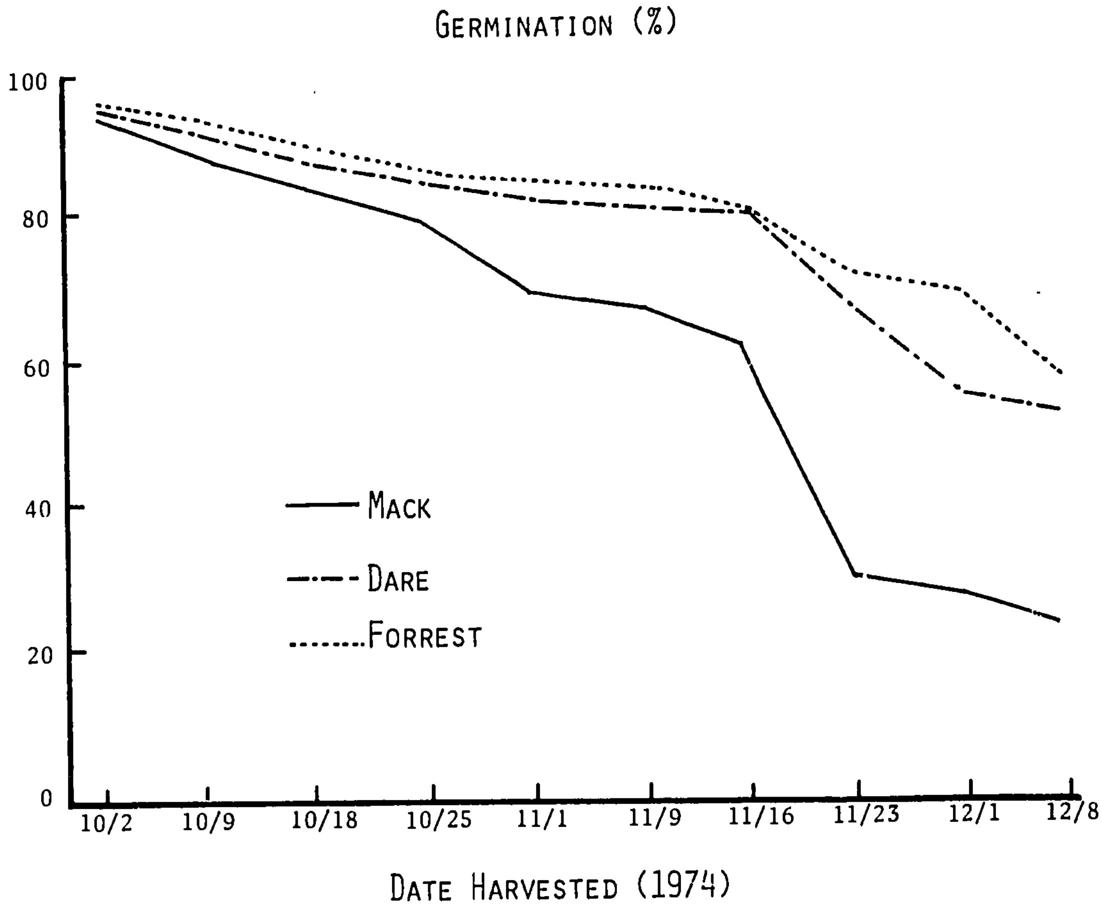

Fig. 1. Germination of Mack, Dare, and Forrest soybean seeds harvested at weekly intervals beginning October 2, 1974. Harvest maturity stage (14 to 16 percent moisture) was reached on October 2.

Table 2. Effect of Seed Moisture Content and Temperature on Germination Percentage of Soybean Seeds During Storage

Moisture (%)	Temperature (°C)	Approximate number of years in storage 0.5	1	2	3	4	5	10
9.4	10	93	95	98	93	99	92	94
	20	97	99	96	94	89	90	0
	30	96	87	0				
13.9	10	95	98	96	92	88	49	0
	20	98	93	0				
	30	0						

Source: Toole and Toole, 1946 (56).

humidity is sufficiently low; (2) reduction of relative humidity to a favorable level by conditioning of the storage environment (dehumidification); and (3) packaging the seed in a moisture vapor impermeable container, e.g., metal or plastic film, at a moisture content that is in equilibrium with the desired level of relative humidity.

Emphasis in seed storage operations is most often placed on the controlling influence of relative humidity on seed moisture content. This emphasis is proper during the packaged seed storage phase provided the packaging material is not moisture vaporproof. The hygroscopic equilibrium between seed and the ambient relative humidity, however, is two-way. In bulk storage or storage in a moisture vaporproof package, the relative humidity in the package or in the pore spaces in a large mass of seed stored in bulk is determined by the moisture content of the seed.

In addition to its direct effect on seed moisture content, the relative humidity of the storage environment has indirect effects on seed quality. The comprehensive studies of Christensen and associates (17) have demonstrated that (1) storage fungi are a major cause of quality losses in stored grain and seed; (2) the important storage fungi cannot grow and reproduce on grains or seeds in equilibrium with a relative humidity less than 65 to 70 percent; and (3) drying seeds or grain to a moisture content in equilibrium with a relative humidity below 65 to 70 percent, and maintaining it at that level during storage, eliminates storage fungi problems regardless of other conditions of storage. The activity and reproduction of storage insects also decrease rapidly as relative humidity drops below 50 percent, and reproduction stops altogether at less than 35 percent relative humidity (18).

SEQUENCE OF DETERIORATIVE CHANGES

Deterioration of seed is characterized by change. Indeed, in a practical context, deterioration and change—detrimental change—are almost synonymous since the onset and progress of deterioration in seeds is identifiable primarily in terms of measurable or observable changes in their response-reactions (19, 20). Conversely, of course, detrimental changes in response-reactions of seeds are considered to be the result of deterioration. The detrimental changes caused by or associated with deterioration are also the *consequences of deterioration* in terms of their effect on the propagative qualities of seeds.

Delouche and associates (20, 26, 27) characterized deterioration of seeds as inexorable, irreversible, minimal at the time of physiological maturity, and variable in rate among seed kinds, cultivars, seed lots of a cultivar, and individual seeds within a lot. They also pointed out that deterioration is progressive, that specific components of seed performance are affected by different levels of deterioration, and that loss of germinability is the final—and most disastrous—consequence of deterioration.

On the basis of available evidence and the concepts that deterioration of seeds is progressive and that loss of germinability is the final consequence, Delouche (20) constructed a "probable" sequence of deteriorative changes in seeds, as follows:

1. Degradation of cellular (and subcellular) membranes and loss of permeability control;
2. Impairment of energy-yielding and biosynthetic mechanisms;
3. Reduced respiration and biosynthesis;
4. Reduced rate of germination and early seedling growth;
5. Reduced storage potential;
6. Reduced rate of plant growth and development;
7. Decreased uniformity of growth and development among plants within the population;
8. Increased susceptibility to environmental stresses, especially during germination, emergence, and early seedling development;
9. Decreased yield;
10. Decreased emergence percentage;

11. Increased percentage of abnormal seedlings; and
12. Loss of the capacity to germinate.

The postulated sequence of deteriorative changes in seeds emphasizes the increasing severity of the changes, or rather their consequences, as related to performance capabilities of the seeds. A seed that has lost the capacity to germinate has zero capabilities. It does not follow, however, that a seed that has maintained its germinative capacity has 100 percent capabilities. Depending on the progress of deterioration, a germinable seed's capabilities might be anywhere between near 0 and 100 percent. Reading the sequence of deteriorative changes "backward," i.e., from loss of germinability to the onset of membrane impairment, it is evident that a seed might be capable of germination in a germination test but not of emergence even under favorable conditions. Continuing, it might germinate and emerge in the field—but slowly—and develop into a weak seedling that succumbs to an environmental stress. Or, the seedling might survive but grow and develop more slowly, flower later, and yield less than a plant from a seed that was less deteriorated. The consequences of deterioration less disastrous than loss of germinability fall within the providence of vigor (20, 27), a subject that will be considered later.

The progressive impairment of response-reactions and performance capabilities of seeds during deterioration are evident in the data presented by Byrd (12) and Byrd and Delouche (13) from their studies on the deterioration of soybean seeds in storage. Various response-reactions of the seeds were determined at monthly intervals during storage at 30° C and 50 percent relative humidity (Table 3). Standard germination percentage did not significantly decrease until 7 months. However, germination percentage following accelerated aging and a brief immersion of the seeds in 75° C water and emergence in the soil cold test significantly decreased after 1 to 3 months' storage. Over 7 months, storage deterioration did not progress to the point where germinability in a laboratory test was affected, but it had progressed sufficiently even after one month to reduce the resistance of the seeds to environmental stresses such as the high temperature and relative humidity of accelerated aging. Other performance parameters measured such as rate of seedling growth and respiratory activity, did not decrease in value before loss of germinability in Byrd's study. Other investigators (3, 45, 53), however, have demonstrated that decreases in rate of germination and seedling growth and in respiratory activity precede loss of germinability in soybean seed.

Since substantial losses in the performance capabilities of seed, i.e., seed quality, occur before the standard germination percentage decreases, quality assurance programs should incorporate several additional and more sensitive tests for monitoring the progress of deterioration during storage of seeds.

PHYSIOLOGY OF DETERIORATION

In a recent paper, Abdul-Baki (1) proposed that, on the biochemical level, three

Table 3. Comparison of Several Quality Tests Conducted at Monthly Intervals on Soybean Seeds Stored for Nine Months at 30° C, 50 Percent R.H.

Months in storage	First count germ. (%)	Std. germ. (%)	Accelerated aging (%)	Heat treatment (%)	Cold test (%)	Root growth (3 days) (mm)	Root growth (4 days) (mm)	O_2 Consumed (ul)	R.Q.
0	96	97	93	90	89	41	86	21	0.79
1	94	96	83	73	89	36	75	25	1.07
2	93	95	76	91	85	38	83	21	0.88
3	95	98	70	93	76	35	77	23	0.98
4	96	99	75	61	84	45	87	27	0.84
5	88	93	47	67	33	37	72	24	1.07
6	86	92	29	56	13	36	76	23	1.13
7	84	90	30	10	3	21	48	15	1.70
8	43	47	0	0	0	16	38	20	1.38
9	53	56	0	0	0	15	30	12	2.15

Source: Byrd, 1970 (12).
Note: All values underlined are significantly different from those for the 0 months' storage period.

conditions must be met for seeds to attain and maintain their full performance capabilities (i.e., vigor): (1) a highly organized organelle/membrane system must be established during seed development; (2) disorganization of the organelle/membrane system during post-maturation dehydration must occur in an orderly manner such that it can be rapidly reorganized upon rehydration; and (3) during rehydration, all membranes must be well organized before the seeds become fully hydrated.

Impairment of the integrity of the organelle/membrane system in seeds, or perhaps the capacity to reorganize promptly and properly during rehydration, is considered to be a fundamental deteriorative change. It has been known for many years that aged, deteriorated seeds "leak" greater quantities of amino acids, sugars, electrolytes, and so on when soaked in water as compared with "new" or vigorous seed. This phenomenon is the basis for the so-called conductivity (or resistance) tests for seed vigor (9, 58).

Abu-Shakra and Ching (4, 5) studied mitochondrial activity in germinating new and old soybean seeds. They found that new and old soybean seeds exhibited differential phosphorylative efficiency. The P/O ratio of mitochondria from aged seeds was only 40 to 70 percent that of new seeds. Electron micrography revealed that the mitochondria from old seeds had dilated or inflated cristae, coagulated matrices and disrupted outer membranes.

Damage to, or impairment of seed membranes—including those of organelles—has been attributed to autoxidative/peroxidative reactions involving free radicals. Villiers (57) pointed out that the most likely mechanism of membrane impairment is peroxidation/autoxidation of the unsaturated lipids. Polyunsaturated lipid components of the membrane can react in the presence of oxygen to form free-radical intermediates and unstable peroxides, which can result in the destruction of the lipid itself, or the formation of insoluble lipid-protein complexes by cross linkage. In a very recent paper, Stewart and Bewley (51) presented evidence obtained from studies of aging in soybean axes, which in their view suggested that peroxidative changes in lipids were involved in aging and contributed to loss of viability. Changes in phospholipids during storage of soybean seeds have also been reported by Chapman and Robertson (14), but they attributed them to uptake of hygroscopic moisture during storage. Parrish and Leopold (44) found that accelerated aging of soybean seed resulted in reduced "vigor" and early respiratory activity, increased leakage of electrolytes, and losses in dry weight. They concluded that each of the changes measured can be interpreted in terms of deteriorative changes in the membranes. They hedged, however, in attributing membrane deterioration to peroxidation/autoxidation reactions involving free radicals. In a subsequent study, Priestley and Leopold (48) found that lipid oxidation was apparently unrelated to the process of aging in soybean seeds.

A major line of evidence for the membrane impairment hypothesis of seed deterioration is the phenomenon of increased "leakage" of electrolytes, amino acids, sugars, and so on, associated with aging or loss of vigor. While this line of evidence is generally accepted, Abdul-Baki and Anderson (2) cautioned that apparent leakage of sugars might be better interpreted as a decrease in sugar utilization capacity rather than a quantative increase in leakage per se. Other evidence that membrane impairment is involved in loss of performance capabilities of seed includes the close association of membrane leakage with chilling stress to seeds during imbibition, which can severely reduce vigor and germination of seeds (11, 43), and the recent report that methanol stress of soybean seeds results in "physiological" lesions that increase membrane leakage, depress cyanide sensitive respiration, and reduce chlorophyll synthesis (40), thus, mimicking changes during accelerated aging.

The reduction in respiratory activity associated with aging and imbibitional chilling injury of seeds (i.e., soybean seeds) is an expected consequence of membrane impairment since respiration within the mitochondrion is a function of "unit membranes" (3, 37, 38, 49). Leopold and Musgrave (38) found that unaged soybean seeds utilize both the cytochrome oxidase and the alternative pathway. In aged seeds, on the other hand, respiration is sharply reduced, especially through the cytochrome pathway while the alternative pathway is engaged. They suggested that the lowering of respiratory activity and the shift in pathways may play an important role in the decline of germinability and vigor.

Ching (15) has been the principal proponent of the association of ATP content with seed vigor (hence, with seed deterioration). Anderson (6) presented evidence that the low rates of protein synthesis in slightly deteriorated soybean seeds were not due to losses in ribosomal or soluble fraction activities, but rather to reduced ATP content. Adenine and adenosine conversions to ATP were reduced in deteriorated axes, and these reductions were, in turn, reflected in reduced incorporation of these components into RNA.

The reduction in biosynthetic activity (protein synthesis) associated with aging reported by Anderson (6) extended the observations reported earlier by Abdul-Baki and

Anderson (3) and Yaklich and Abdul-Baki (58) that the rate of incorporation of radiolabeled leucine and P into macromolecules, i.e., biosynthesis, decreases as the degree of seed deterioration increases.

The other consequences of deterioration—reduced rate of germination and seedling growth, reduced rate of plant growth and development, reduced storability, increased sensitivity and susceptibility of the seed system to environmental stresses, such as sub- and supraoptimal temperatures, inadequate oxygen supply, and mechanical impedance to emergence (soil crusting)—naturally follow the sequence of membrane impairment, reduced respiratory activity, and biosynthesis.

The physiology of deterioration has a pathological dimension. Harman and Garret (31) showed that pea seeds inoculated with *Aspergillus ruber* deteriorated much more rapidly in storage than uninoculated seeds. Other evidence of deterioration, such as shrunken cytoplasm, coalesced lipid vesicles, disordered ribosomal matrices, and damaged mitochondria were more pronounced in inoculated than uninoculated seeds. Soybean seeds stored at 13 percent moisture and 5° C for 480 to 500 days increased only slightly in fat acidity and in invasion by storage fungi, while seeds at 13 and 14 percent moisture at 25° C increased appreciably in fat acidity and invasion by storage molds, especially at the higher moisture content (16). Kennedy (36) reported that under experimentally controlled situations, invasion by fungi, especially *A. glaucus*, can account for serious damage to soybean seed in storage. Nicholson et al. (41) found that *Sclerotinia sclerotiorum* and *Phomopsis* sp. are internally seedborne in soybeans and can inhibit germination in vitro and field emergence, while Tenne et al. (55) documented changes in viability and microflora of soybean seed stored under the humid conditions in Puerto Rico.

Tachibana et al. (52) described a type of cotyledonary necrosis in soybean seed. The necrosis is noninfectious and results from physiological deterioration of the cotyledonary tissue caused by weathering. Bacteria and fungi associated with the necrotic tissues are secondary invaders.

The several other theories of seed aging or deterioration have been reviewed by James (33), Roos (50), and Villiers (57). They include (1) autotoxification of the seed system by accumulated deleterious metabolites that render enzymes, nucleic acids, and membranes nonfunctional; (2) "wear and tear" of cells, organelles, and metabolic machinery until they become too inefficient for resumption of active growth, i.e., germination; and (3) somatic mutations that accumulate until they render the essential systems and mechanisms inoperative.

Somatic mutations that accumulate during aging and lead to genetic changes, as well as death, are of special concern in the long term preservation of germplasm. Roos (50) pointed out that the chromosomal aberrations that accumulate during storage are probably eliminated during the growth and reproductive stages of the plant and, thus, are of little consequence in altering the genetic makeup of the next generation. However, they do appear to contribute to the increased incidence of seedling abnormalities characteristic of aging seed. Considering point mutations, Roos felt that from the standpoint of germplasm preservation, accumulation of mutagenic changes during reproductive cycles adds to the total genetic variability of the species—a major goal of germplasm conservation. In Roos's view, the most serious threat to the genetic makeup of a population of seed is natural selection during storage and regeneration, i.e., differential longevity, variations in resistance to seedbed stresses, differences in seed production, and so on.

VIGOR

The objectives of this paper did not include a discussion of vigor. Yet, vigor and deterioration are, in my view, so closely related that the subject of vigor cannot be completely ignored.

Seed vigor and deterioration are like the opposite faces of a coin. The reality is the same, but the views are from different perspectives. Vigor has a positive connotation, while deterioration has a negative connotation.

In seed vigor research and development work, attention is focused on consequences of deterioration less severe than loss of the germinative capacity, since this final and most disastrous stage of deterioration is adequately monitored by the standard germination test. A major objective of vigor evaluation is the identification of seed lots that show acceptable germination but that have deteriorated to the extent that the probability of their satisfactory performance in the field—i.e., emergence, stand establishment—is not favorable. In some cases the objective is to identify seed lots with minimal deterioration and very superior field performance capabilities.

Most of the methods used to evaluate seed vigor are the same as those used in research on seed deterioration (3, 9, 34, 45, 53, 59, 60). Indeed, a substantial portion of the information on seed deterioration derives from studies of seed vigor.

Estimates of the performance potential of seed obtained from vigor evaluations are relative. The reason for this situation is that one of the most practically significant manifestations of deterioration—or reduced vigor—is an increased sensitivity of the seed to environmental and physical stresses in the seedbed. Since the actual performance of the seed when planted depends not just on the level of deterioration of the seed, but also on the severity of the stresses and their interaction with the seeds, vigor evaluation could only be absolute if the stresses were controlled. This is not possible.

Despite the relative meaning of vigor test results, they are important in quality assurance programs including aspects concerned with maintenance and monitoring of seed quality during storage. The most effective vigor tests for soybean seeds are the tetrazolium assay, the accelerated aging test, and the rate of seedling growth evaluation (9).

SUMMARY

Physiological changes occur during seed storage that impair various functional elements and systems, reduce performance capabilities, and ultimately lead to germination failure. These changes are referred to as seed deterioration, an inexorable, progressive, irreversible process, the rate of which is influenced by inheritance, the quality of seeds as they enter storage, temperature, and seed moisture content/relative humidity. Problems associated with soybean seed storage are more difficult and severe than for most other kinds of seeds because the seeds of modern cultivars are inherently short-lived.

The evidence is very substantial that impairment of the membrane systems in seed is a fundamental event in the process of deterioration. This event leads to a loss of efficiency in respiration and biosynthesis, which in turn leads to a reduction in speed of germination and seedling growth, an increase in the susceptibility of the seed to stress, an increase in the incidence and severity of seedling abnormalities, and ultimately to loss of the capacity for germination.

Deterioration and vigor are essentially antonymous. They represent the negative and positive aspects, respectively, of a seed or seed lot's physiological condition.

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DISCUSSION

Bhatnagar: The deteriorative effects of physiological changes have been well elaborated, but what were the precise changes referred to in the title of the paper?

Delouche: I'm afraid that I've labored under the impression that the talk and paper I prepared addressed in a rather comprehensive way the physiological changes that occur during storage of soybean seeds, or other kinds of seed. In my view, impairment of membrane systems, reduced respiratory activity, reduced rate of germination and seedling growth, reduced emergence potential, loss of germinative capacity, and so on, are physiological changes highly relevant to our concerns in this conference. I do admit to some neglect of various speculations and theories related to seed aging in my oral presentation. They will be reviewed in the paper.

Kueneman: Do some soybean lines having superior seed storability also have superior weathering resistance? If so, are you surprised?

Delouche: No, but I would be surprised if storability and weathering resistance were not closely related.

Joshi: What does the soybean plant look like at physiological maturity (of the seed) under tropical conditions?

Delouche: I assume it would look like a soybean plant at the same stage under temperate conditions, viz., leaves still on although yellowing somewhat, pods yellowish green, seed still elongated, rather soft, about 50 to 55 percent moisture content, wet basis.

Quebral: Do you have any experience in hermetic storage, either underground or underwater?

Delouche: Yes, with hermetic storage in *airtight* containers such as metal cans in a regular or conditioned storeroom but not underwater or underground. I assume the only advantage of storing seed in airtight containers underground or underwater would be a generally lower temperature, which would increase longevity.

Petcharat: You showed slides illustrating plants produced from low, medium, and high vigor seed. Differences in yield are evident. My question is: if more fertilizer had been applied to the plants from the low vigor seed, would they have looked like those from the high vigor seed?

Delouche: I don't know. Possibly. In the particular research illustrated, seed vigor was the variable studied. Cultural practices, fertilization, and plant population were constant among the seed vigor levels.

Tedia: In tropical countries soybean seeds appear to deteriorate at moderate to high temperatures even though moisture content is 7 to 8 percent. Has this been looked into?

Delouche: Not very well. Seeds do, of course, deteriorate at warm temperatures even though moisture content is low. Low moisture content soybean seeds and the seeds of other grain legumes often do germinate rather slowly and poorly. This sort of response might be related to imbibitional stress rather than deterioration because conditioning the seed slowly to a higher moisture content (above 10 percent) in a humidity chamber frequently results in normal, much improved germination.

The Microorganisms of Stored Soybean Seeds

P.R. HEPPERLY, J.S. MIGNUCCI, AND J.B. SINCLAIR

Sizable losses occur during storage of soybean seeds under tropical conditions. According to FAO, storage losses account for one-quarter to one-third of grain harvested in India, Africa, and South America (24). Considering the protein and calorie deficit occurring in these areas, the solution of storage losses is of great importance.

The International Soybean Program (INTSOY) is working to increase tropical production and utilization of soybeans (35). The high yield of soybeans has been demonstrated in a multitude of tropical sites through the INTSOY International Soybean Variety Evaluation Experiment (ISVEX) (39). A major obstacle in tropical soybean production and utilization is the deterioration of seeds in storage. For this reason, INTSOY has devoted attention to analyzing the problems of storing soybeans under tropical conditions.

Little work has centered on the action of microorganisms on soybeans and other grains under tropical conditions. Most work has been with cereal grains in temperate zones. Early studies concentrated on the effects of storage time, temperature, and humidity without regard to the role and action of microorganisms. Nevertheless, research in the last 30 years demonstrates pest and pathogen activity as leading causes of reductions in seed viability, vigor, and quality during storage.

In storage, the soybean seed is part of a complex ecosystem including the microorganisms (fungi and bacteria) and the animals (arthropods and vertebrates) that feed on it and physical factors, such as temperature and humidity. The environment not only affects soybean seeds directly but also indirectly by influencing the action of associated microorganisms and arthropods. The complexity of the grain storage ecosystem warrants inter- and multidisciplinary studies involving plant pathologists, entomologists, food scientists, agronomists, plant physiologists, agricultural engineers, and analytical chemists.

This article reviews the importance of microorganisms on soybean seeds in storage and highlights areas deserving further effort and greater control.

LITERATURE REVIEW

The Role of Fungi

There are over 100,000 species of fungi, of which less than one-half have been described (6). Over 100 species of microorganisms (fungi, bacteria) and viruses have been associated with soybean seeds (51, 66, 67, 73). Fungi constitute approximately 80 percent of the total species of microorganisms recorded on soybeans.

Fungi can be classified as decomposers (decay organisms), parasites, or as symbionts. The decay activities of fungi are extremely important in cycling of nutrients and in development of soil fertility (45). The parasitic and saprophytic actions of fungi also are an important cause of serious losses in grains.

Fungi associated with soybean and other grain seeds are divided in two groups, based on time of seed infection (11). Infection by "field fungi" occurs in the field, and infection levels are static or decrease under storage conditions. "Storage fungi" usually infect and develop on seeds in storage and are not in high incidence on seeds before harvest. Each of these groups shows adaptations to the distinctly different field and storage environments.

Field fungi vary from storage fungi in needing free water and higher relative humidity for infection and development. Field fungi can cause losses in germination and seed discolorations (3, 67). Species of

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Cercospora, Colletotrichum, Fusarium, and *Phomopsis* are common field fungi causing losses in soybeans. Under rainy conditions, plants may be infected throughout their life-cycle; yet, disease symptoms and damage usually are found in early seedling stages and during stages of reproduction and senescence. The latent ability of these fungi to infect soybeans is important to their survival. These fungi do not readily colonize debris in soil and have low competitive ability as saprophytes. Their parasitism is not specific to soybeans as found in certain obligate parasites, for example, soybean downy mildew; moreover, they are easily cultured on laboratory media.

Internally seedborne fungi of soybeans generally are concentrated within the seedcoat, in the endo- and mesodermal layers before germination. The seed discolorations they cause are important grading and quality factors (2). Losses in seed germination and vigor are important to seed producers and farmers. The commercial uses of infected soybeans may be hampered and oil quality may be reduced (34). Also, the survival and activation of these infections serve as primary foci for disease outbreaks. Thus, diseases are spread from season to season and from contaminated to disease-free areas.

Neergaard (49) reviewed the maximum reported survival of field fungi in stored seeds. Depending on the order or family of fungi there were differences in their survival on stored seeds. Fungi such as *Colletotrichum* and *Phomopsis* that produced their conidia in fruiting bodies survived from four to six years. Dark-spored asexual fungi survived from six to eight years and sclerotial or teliosporic fungi (ergots, Sclerotinias, and smuts) survived from eight to fifteen years. Nicholson and Sinclair (50) found substantial reductions in seedborne *Colletotrichum dematium* var. *truncata*, cause of soybean anthracnose, when seeds were stored at room temperature in India. The same seeds were not reduced in *C. dematium* var. *truncata* incidence if stored under refrigeration for six to twelve months. Since the death of internally seedborne field fungi usually indicates losses of vigor in stored seeds, storage for reduction of seedborne fungi cannot be recommended.

After the seed has been placed in storage, it may become infected by fungi that thrive without free water if relative humidity is high in the grain mass. These fungi grow at relative humidities over 60 percent or when soybeans are above 12 percent in moisture. The most common storage molds of soybeans are *Aspergillus* and *Penicillium spp.*

Aspergillus and *Penicillium spp.* are closely related and interact significantly with man (59, 60) (Fig. 1). Characteristics of these fungi include high competitive saprophytic ability, rapid and profuse reproduction, ability to grow under extremes of humidity and temperature (Tables 1 and 2), antibiotic production, and ability to utilize a large range of substrates based on efficient production of adaptive enzymes (33).

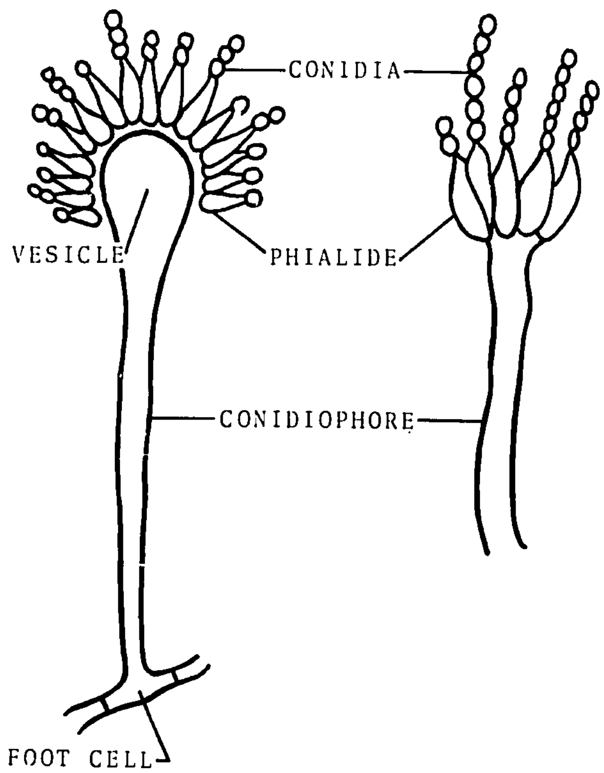

Figure 1. Conidiophore morphology in *Aspergillis* and *Penicillium*. Adapted from Raper and Thom (60).

Table 1. Minimum Relative Humidity Percentage Permitting Development of Aspergillus, Penicillium, *and Species of Field Fungi*

Fungus group	Minimum percentage relative humidity
Aspergillus restrictus	68-70
A. glaucus	70-73
A. candidus	75-80
A. ochraceus	80
A. flavus	85
Penicillium spp.	80-90
Field fungi	95-100

Adapted from Christensen (9).

Table 2. Minimum, Maximum, and Optimum Temperatures for Development of Storage Fungi

Fungus group	Temperature (°C) Minimum	Maximum	Optimum
Aspergillus restrictus	5-10	40-45	10-35
A. glaucus	0-5	40-45	30-35
A. candidus	10-15	50-55	40-45
A. flavus	10-15	45-50	40-45
Penicillium spp.	-5-0	20-25	35-40

Adapted from Wallace (76).

They degrade food products, wood, optical equipment, and fabrics, besides grains. The toxins these fungi produce may be of importance in plant and animal diseases. Fungal spores of these genera cause chronic allergies, particularly for farmers and agricultural workers. On the other hand, these fungi have been useful in food fermentation and production of enzymes, organic acids, and antibiotics. Recently, the inoculation of seeds, including soybeans, was found effective for the biological control of soilborne damping-off fungi (43).

Aspergillus. Within the genus *Aspergillus,* 80 species have been described, 26 of which are found in grain in storage (59) (Table 3). *Aspergillus spp.* are cosmopolitan

Table 3. Groups of Aspergillus *Species*

Aspergillus candidus[a]	*Aspergillus niger*
A. cervinus	*A. ornatus*
A. clavatus	*A. ochraceus*[a]
A. cremeus	*A. restrictus*[a]
A. flavipes	*A. sparsus*
A. flavus[a]	*A. terreus*[a]
A. fumigatus[a]	*A. ustus*
A. glaucus[a]	*A. versicolor*[a]
A. nidulans	*A. wentii*[a]

[a]Often associated with grain in storage.

and found on a wide range of substrata either of plant or animal origin. A large number of these organisms are associated with soil- and airborne conidia and are common in spore traps even over the middle of the Atlantic Ocean (75).

The variation of *Aspergillus spp.* does not permit easy determination at species level. *Aspergillus spp.* are separated in groups of similar species. Most pathologists have used the 18 groups of *Aspergillus* as species differentiations. The limits of speciation could be the most confusing aspect of working with this genus.

Groups of *Aspergillus* are consistent in their physiological requirement for relative humidity. The groups most common in stored grains *(A. glaucus, A. restrictus, A. candidus, A. versicolor, A. ochraceous,* and *A. flavus)* have increasing requirements for relative humidity (48). Species of the Glaucus groups *(A. amstelodami, A. ruber, A. chevalieri)* and the *Restrictus* group have spores that can germinate when relative humidity is slightly above 60 percent. In soybeans relative humidity reaches the 60 percent level when seeds have 12 to 13 percent moisture. The *Aspergillus* group *A. candidus, A. ochraceous,* and *A. flavus* have minimum humidity requirements of 75, 80, and 85 percent, respectively.

Biological succession in stored grain can bring about combustion of heating of large grain masses. Ramstad and Geddes (58) demonstrated that heating of soybeans was related to microbial respiration rather than by respiration of soybean seeds. *Aspergillus restrictus* and *A. glaucus* groups develop in pockets where seed moisture is between 12 and 13 percent (9, 10, 19). Grain masses with average moisture below 12 percent can develop localized areas of higher moisture due to moisture migration. Grain dealers mix moist grain with drier grain to meet the minimum average moisture requirements for different grades, but these actions tend to create moist pockets of grain (Table 4). Another consideration is insect activity, which can occur if grain has over 9 percent moisture. This activity can produce heat and moisture sufficient for pioneer fungi *(A. restrictus* and *A. glaucus* groups). Activity of these fungi plus the activity of mites cause additional increases in temperature and humidity to the point where *A. candidus* and *A. flavus* groups become dominant. *Aspergillus candidus* and *A. flavus* thrive at from 14.5 to 16.5 percent and from 16.5 to 18.5 percent seed moisture, respectively. Having optimum growth at above 40° C, these fungi can raise grain temperature to a maximum of 50° to 55° C. At these temperatures the action of thermophilic bacteria and fungi can bring temperatures to 70 to 75° C, where chemical reactions are autocatalytic and rapid combustion and destruction of the mass occurs.

Table 4. Percentage of Seed Moisture of Soybeans and Other Grains and the Equilibrium Relative Humidity for Intergrain Air Spaces at 25° to 30° C

Equilibrium relative humidity (%)	Percentage of seed moisture		
	Oil seeds		Cereal seeds
	Soybean	Sunflower	Corn, rice, and wheat
65	12.5	8.5	13.5
70	13.0	9.5	14.5
75	14.0	10.5	15.5
80	16.0	11.5	16.5
85	18.0	13.5	18.5

Adapted from Moreno and Zamora (48).

Even without heating of grains, activity of *Aspergillus spp.* are important causes of loss in seed viability. Harman (28, 29) found that *A. ruber* killed the embryo of peas by the production of a toxin. Pathogenicity of *Aspergillus spp.* varied between peas, squash, tomato, and wheat. Isolates of *A. glaucus*, *A. restrictus*, and *A. flavus* killed seed of both wheat and peas. Squash was affected only by *A. flavus*, and tomato was not affected by any of the fungi.

Toxins produced by *A. flavus*, aflatoxins, can be important to animal health and in seed quality. Diener and Davis (17) found aflatoxin production in the majority of *A. flavus* isolates from the southeastern part of the United States. Bean et al. (4) detected aflatoxin in soybean-based concentrates of chicken feed. Demeyers and Bean (15) compared aflatoxin production of *A. flavus* isolates both on soybean- and peanut-based substrates and found 64 percent less aflatoxin for soybean-based substrates as compared with those of peanut. Recent work suggests that zinc availability is crucial to aflatoxin production by *A. flavus*. In soybeans, phytic acids bind zinc and make it unavailable to *A. flavus*.

Unlike the *A. glaucus* and *A. restrictus* groups, *A. flavus* invades high percentages of seed in the field, especially if conditions of drought, high temperature, and high level of insect damage occurs (16). Selective media for *A. flavus* isolates and strains producing af! oxin have been developed (5, 7, 36, 44).

Commercial seeds infected with *Aspergillus spp.* can lose grade due to mustiness, discoloration, loss of weight, and chemical changes. Seed lipids are the chemical fraction most vulnerable to breakdown (18, 40, 41). *A. glaucus*, *A. candidus*, and *A. flavus* groups have high lipolytic ability (25, 60). Infection of soybeans by these fungi increases fatty acids and lowers the yield and quality of extracted oil (11, 40).

Penicillium. Next to *Aspergillus*, *Penicillium* is the most important and common genus of storage molds. Of the over 150 species of *Penicillium* described, 50 have been associated with stored grain (60). *Penicillium spp.* generally are less tolerant to low relative humidity than species of *Aspergillus*. Relative humidity above 80 percent is needed for development in this genus. Unlike *Aspergillus spp.*, certain *Penicillium spp.* are tolerant to extremely low temperatures and grow actively at freezing and below (53). For this reason, *Penicillium* has frequently been reported on high moisture seeds under refrigeration and on certain seeds stored at high latitudes (76). The actions of *Penicillium* on stored seeds have been studied less than those of *Aspergillus*. *Penicillium oxalicum*, which has been used experimentally as a biological control of soilborne pathogens, is applied as a seed treatment in peas, but is pathogenic to corn and soybeans (63). Besides colonizing soybean seeds, *Penicillium spp.* are reported as colonizers of refrigerated food products, including soy foods (52).

The Role of Bacteria

The activities of bacteria and their role in soybean seed health are much less understood than those of fungi. Bacteria of three genera are common causes of disease on adult soybean plants in the field (67). These genera (*Corynebacterium*, *Pseudomonas*, and *Xanthomonas*) are all seedborne. Graham (26) found *Pseudomonas glycinea*, cause of soybean bacterial blight, survived a few months in stored seeds; whereas, *Xanthomonas phaseoli* var. *sojensis*, cause of soybean bacterial pustule, survived up to 30 months in the same. The greater longevity of *Xanthomonas* was attributed to the production and activity of xanthans.

Bacillus subtilis has been found to increase drastically on seeds stored under ambient conditions in the humid tropics and has been associated with seedling decay at temperatures above 30° C (61) (Table 5). Schiller et al. (64) and Ellis et al. (22) showed that soybean seeds treated with penicillin or streptomycin controlled *B. subtilis* and resulted in higher germination than that of nontreated seeds.

Table 5. Effect of Time of Soybean Storage under Tropical Conditions on Bacillus subtilis *Incidence and Germination*

Months of storage	Incidence of *B. subtilis*	Germination (%)
0	18	84
3	38	62
6	81	16
9	100	0

Adapted from Ravalo et al. (61).
Note: Seeds assayed at 35° C on cellulose pads.

Interactions of Anthropods and Microorganisms in Stored Grain

There is little information on the interactions of bacteria and arthropods on stored grain. Insects and mites interact with field and storage fungi (65). Eighty percent of storage mites and 60 percent of storage insects can be cultured on field or storage fungi as their sole food source (69). Daugherty (12, 13) found that field stinkbugs vectored *Nematospora coryli*, the soybean yeast spot organism. Stinkbug damage reduced seed viability, oil quality, and seed storability. Agarwal et al. (1) reported weevils as vectors of storage fungi, especially *A. glaucus* species. Seven *Aspergillus spp.* and five *Penicillium spp.* were reported from surface-sterilized weevils in grain in Pakistan (76). Mites have been found consumers of both field and later storage fungi (27, 70). Forty species of mites were found on various grains in Canada (76). In Pakistan, four *Aspergillus spp.* and seven *Penicillium spp.* were isolated from surface-sterilized mites from grain.

Control of Microorganisms in Storage: Physical Factors

Roberts (62) found that seeds of three different species all deteriorated according to temperature and humidity in storage. For each 1 percent reduction in seed moisture or 5° C reduction in storage temperature, storage life of seeds may be doubled. Control of storage deterioration is based mainly on maintenance of temperatures and humidities below the minimum for growth of storage microorganisms (Table 6). Such strategy

Table 6. Deterioration of Soybean Seeds Stored at 80% Relative Humidity and 30° C

Weeks of storage	Percentage of germination[a]
0	88
4	80
8	11
12	less than 1

Adapted from Minor and Paschal (47).
[a]Means are based on over 300 lines of maturity groups VIII, IX, and X.

depends on moisture testing to ensure the humidity of seed less than 12 percent seed moisture before entering storage, and continued monitoring to ensure moisture levels are not raised by reabsorption of humidity. Reabsorption is not problematic in areas where the average relative humidity is less than 60 percent, but the possibility of dried seeds reabsorbing moisture up to levels that stimulate storage microorganisms is a constant threat Dried seeds can be more safely stored i vaporproof materials that are well-sealed (30, 31, 37) (Table 7).

Table 7. Effect of Soybean Storage Time and Container on Seed Germination

Storage container	Storage time 3 months	6 months	9 months
Sealed can	88	70	44
Fertilizer (plastic-lined)	80	54	20
Cloth bag	50	0	0

Adapted from Ravalo et al. (61).
Note: Seeds were 10 percent moisture before storage, which was under ambient temperature and humidity in Mayaguez, Puerto Rico.

Saul et al. (63, 71) found that carbon dioxide generation can be used to determine the likely storability of seeds. Respiration rates were mainly governed by microbial activity and its increase with mechanical damage of seeds (74). Since respiration is governed by availability of oxygen, storage of seeds in altered atmospheres should be feasible. In Bermuda, pigeon peas *(Cajanus cajan* (L.) Millsp.) are stored in sealed drums already densely packed with grain. These drums become oxygen depleted and carbon dioxide enriched. The altered atmosphere effectively controls weevils and ambient storage can last three to five years.

Monitoring Methods

Of all the methods of monitoring the quality of grain in storage, microbial analysis is the best indicator (75). This process is too specialized for most commercial uses, but it is well suited to critical research. In commerce, a quick test for aflatoxins and monitoring for heating of grain masses are widely used (75). Although aflatoxin contaminated grain cannot now be fed in the United States, latest information indicates that treatment with aqueous ammonia can deactivate the toxin (8). Verification and use of this method should lead to mitigation of storage losses caused by *A. flavus*. Continued and expanded use of grain aeration and dry equipment may be curtailed by the increasing cost of energy to run them.

Genotypic Variation

There is considerable interspecific and intraspecific variation in maintenance of seed quality in storage. Ewart (23) divided plant species into three categories based on their expected lifespan in storage. Many weed species and small-seeded vegetables and flowers are very long lived; whereas, many grains and particularly oil crop seeds are short-lived. Within soybean germplasm, Delouche (14) commented that the small-seeded forage soybeans were much longer-lived than newer large-seeded grain types that were first developed in the United States. Large seed size is related to a reduced percentage of seedcoat tissues and greater susceptibility to mechanical injury (14). Edwards and Hartwig (21) found that small-seeded soybean cultivars had increased seed vigor compared with large-seeded ones. Paschal and Ellis (54) related small seed size to increased resistance to field deterioration by seedborne fungi (Table 8). Because of the greater difficulty to harvest and maintain high seed quality in the tropics, Hartwig (32) and Singh (68) have suggested that the ideal soybean for the tropics will be relatively small, 11 g to 13 g per 100 seeds. In addition to having small seeds, plants should be well-branched to compensate for uneven stands. Small seed is correlated with higher protein and lower oil content, compared with amounts for big-seeded cultivars.

Hard-seededness is used to refer to some legume seeds that do not absorb moisture in humid conditions that otherwise would stimulate soybean germination. Exactly what causes the waterproofing of hard seeds is not known but it is a trait under genetic control, and conventional breeding and selection can yield hard-seeded cultivars (42). Potts et al. (56, 57) have shown that hard-seeded soybeans are less susceptible to field deterioration by seedborne field fungi. Hard-seeded legumes have greatly increased seed longevity. Minor and Paschal (47) found that of over 300 lines of photoperiod groups VIII, IX, and X, only hard-seeded Barchet maintained high seed viability after six months under simulated tropical storage.

Chemical Control

Seed treatment can be used to inhibit the activities of storage fungi during soybean germination and thus increase stand establishment (20, 74, 75). Chemical control during storage itself has proven less encouraging. Mercury-based treatments were used in proving the role of microorganisms in grain heating (46). Mercury was more persistent and effective than copper-based fungicides. Because of their persistence and hazardous nature, mercury-based materials should only be used in experimentation. Although protectant fungicides such as captan and thiram have been highly effective replacements for mercury fungicidal seed treatments, action in storage has not been demonstrated for these compounds. Use of systemic fungicides such as thiabendazole shows more promise because of their relative nontoxicity towards animals, their increased fungicidal activity and ability to permeate plant tissues (48). Thiabendazole has been used experimentally to disinfect grain seeds from storage fungi and to treat high moisture grains (55). Propionic acid has been used with some success as a preservative in cereal grains stored at high moisture. The demonstration of streptomycin and penicillin for controlling bacterial storage rot at present does not suggest commercial application potential. The widespread medical use of both these antibiotics limits their agricultural use. Measures must be taken to prevent development of antibiotic resistance strains in nature.

Table 8. The Origin, Field Reactions, and Storage Reactions of Soybean Plant Introductions with Resistance to Seedborne Microorganisms

		Field reactions[a]								Storage[b]	
		Percentage total seedborne fungi							100-seed weight	Germi-nation	*Asper-gillus*[c]
Number	Origin	0	2	4	Yield (kg/ha)	Maturity (days)	Lodging		(9)	(%)	(%)
PI 279.088	Tanzania	0	4	11	2597	119	1.7		8.2	49	51
PI 205.912	Thailand	9	9	13	1955	109	2.5		10.6	70	28
PI 341.249	Australia	1	13	20	2741	110	2.0		11.2	76	26
PI 205.907	Thailand	4	7	27	2227	111	1.7		12.1	24	82
PI 239.235	Thailand	2	18	39	2459	119	2.0		11.3	23	77
PI 341.249	Australia	1	13	20	2741	110	2.0		11.2	60	43
PI 219.653	Indonesia	1	14	41	2832	128	3.0		8.2	89	0

[a]Field reaction from Paschal and Ellis Annual Report 1976-77.
[b]Based on germination on cellulose pads after 3 years of ambient storage at Mayagüez, Puerto Rico.
[c]*Aspergillus* spp.

CURRENT RESEARCH AND DEVELOPMENT

The current research in soybean grain storage and the effects of microorganisms should increase focus on control. Programs at the International Institute for Tropical Agriculture (38), INTSOY, and other institutions with mandates to develop soybeans in tropical areas are emphasizing the breeding of soybeans for storability and seed quality under ambient tropical conditions.

Advances that are being made with techniques to permeate seeds with systemic chemicals, including fungicides, may increase in effectiveness and lead to the control of storage fungi. These techniques may be valuable tools for controlling storage microorganisms in the future.

More work should be centered on altered storage atmospheres for controlling storage microorganisms. In the absence of low temperature or humidity soybean seeds could be maintained submerged in oil, as microorganisms themselves often are stored. If such a system was developed, breeders could maintain seed stocks without depending on expensive and unreliable refrigeration.

CONSTRAINTS TO CONTROL OF STORAGE MICROORGANISMS

Solution of storage problems in the tropics, where the losses are greatest, is hampered by the poverty of the small farmers there. Associated with this poverty is a low educational level and reluctance to change traditional practices. Capital often is not available for improving storage buildings and chemicals are too many times not available. These farmers need low technology solutions to their storage problems.

Although low technology solutions may include introduction of improved germplasm, in-country technologies should be analyzed to determine which of these are better than methods developed in high technology areas.

In high technology areas, grain storage will become more difficult as rising energy costs make drying and aeration by conventional methods less economical. Alternative methods should be developed with good ratings in effectiveness, energy requirements and efficiency.

Many current storage problems begin with mechanical damage to seeds in processing, mixing of moist and dry seed, and use of contaminated storage and grain handling facilities. The regulations and norms governing grain practices need to be reviewed periodically to help solve these problems.

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DISCUSSION

P.R. Hepperly: Do the *Aspergillus* survive and grow in soybean seeds that have moisture contents of 7 to 8 percent? Is *Bacillus* a pathogenic or saprophytic?

M.D. Tedia: *Aspergillus* will survive in seeds at 7 to 8 percent moisture, but it will not infect seeds under these conditions. It is necessary for scientists to assay seeds to determine if microflora are playing a role in seed health, not just to assume they don't because of storage conditions or seed treatment. In my experience, I have found that no treatment of this type controls microflora completely.

Some organisms can be saprophytic or parasitic and cause pathogenic changes in infected tissues under certain conditions. *Bacillus subtilis* rapidly degrades soybeans at high temperatures. Treatment with agents such as penicillin or streptomycin decreases *Bacillus subtilis* development at 35° to 45° C and increases seed germination in proportion to this decrease. Published data suggest that *Bacillus subtilis* can be pathogenic to soybeans where soybeans are predisposed by high germination and storage temperatures.

Insects Affecting Soybeans in Storage

SATHORN SIRISINGH AND
MARCOS KOGAN

Unlike other agricultural commodities, soybeans in storage generally do not require special protection against insect infestation. Only a few stored-product insects reportedly are capable of developing on soybeans (10). But with the expansion of soybean production into subtropical and tropical regions and the storage of vast amounts of grain under less than adequate conditions, there is a great need for information on the circumstances under which soybeans become susceptible to insect infestations.

The almond moth, *Ephestia cautella* (Walker) is one of the few insects capable of developing on soybeans in storage. We discuss in this paper results of a series of experiments designed to determine the conditions that permit the almond moth to successfully develop on soybeans.

THE ALMOND MOTH

E. cautella is supposedly of Asiatic origin, but it has spread throughout the world (8). It has been reported to attack many kinds of stored products, including various types of cereals, millets, and oilseeds (20). Recently, it has been observed infesting stored soybeans in India (13, 17). The larva nibbles or cuts small circular holes and consumes parts of the grain. In the process of infestation, the larva also webs together soybean grains and broken grain pieces to use as shelter in which to live and pupate. As a result, the quality of soybeans is lowered by the presence of frass, chewed grains, and webbing materials mixed with the grain. Thus, some factors that may affect development of *E. cautella* on soybeans were studied. This information may be useful in improving conditions capable of preventing or reducing the chance for infestation.

Effect of Moisture Content and Integrity of Soybean Seeds

Wholesome soybeans with low humidity content are virtually immune to insect attack. Bhattacharya (4), studying the susceptibility of several soybean varieties to *E. cautella* in India, noticed that the larvae failed to penetrate the seed coat of some varieties and that the presence of damaged seed coat led to the infestation of the grain by this pest. Like other stored-product insects, the development of *E. cautella* is improved at higher humidity (7, 20). Barnhart (3) stated that at a moisture content below 12 percent, soybeans could be stored for a year or longer without danger of insect damage. Since soybeans are hygroscopic and seeds may reach storage bins already cracked or split during mechanical harvesting or transportation, we tested the effect of moisture content and integrity of the soybean seed on growth and development of *E. cautella* larvae.

After harvesting, "Clark 63" soybean seeds were dried in an oven at 40° C for various lengths of time to obtain seeds with different levels of moisture content. Seeds were tested as whole seeds and as cracked seeds. Soybeans were cracked in a Waring blender operating at full speed for about 5 seconds.

E. cautella larvae failed to develop on whole soybeans with 21.1 percent moisture content, while four larvae could develop on cracked soybeans with moisture content as low as 10.3 percent. On cracked soybeans the number of survivors and the rate of development were also increased with higher moisture contents (Table 1).

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Table 1. Development of E. cautella *on Whole and Cracked Soybeans at Different Levels of Moisture Content*

Soybean	Moisture content (%)	Mean survival to adult from 20 eggs	Mean duration of immature stages (days)	Larvae after 19 days from start of trial	
				Mean survival	Average fresh weight (mg)
Whole seed	21.1	0	...	...	...
	12.8	0	...	...	...
	7.5	0	...	...	...
Cracked seed	18.4	8.5	46.6	10	0.9
	10.3	4	70.6	3.5	0.3

Effect of Different Soybean Particle Sizes

Soybean cotyledons ground to particle sizes ranging from less than 10 mesh to more than 50 mesh did not affect the duration of larval development or the weight gained by the insects (Table 2). Therefore, it is not the size of the particle that determines colonization success but rather the disruption of the seed coat. It is thus apparent that the seed coat is an effective barrier to infestations by *E. cautella* and probably also by other stored grain pests.

Effect of *Diaporthe phaseolorum* var. *sojae* Infected Seeds

Diaporthe phaseolorum var. *sojae* is a common disease attacking soybean seeds in the field. Heavily infected seeds show cracked or shriveled coats and are frequently covered with white mycelium. Lightly infected seeds are generally normal in size and appearance. In view of the disruptive effect of the disease on the seed integrity we decided to test its effect on infestation by *E. cautella*. Some of the *Diaporthe*-infected seeds showed external symptoms while others did not. Only the seeds that showed external symptoms were used. These seeds exhibited various degrees of cracking and shriveling of the seed coats, and some were covered with white mycelium.

Our experiments showed that cracked or whole *Diaporthe*-infected seeds supported larval growth better than cracked or whole uninfected seeds (Table 3). Nearly five times more larvae completed development on cracked infected than on cracked healthy soybeans. No larvae developed on whole healthy soybeans. On the other hand, the seed coat of infected whole soybeans cracked because of the disease, allowing the larvae to penetrate and feed on the cotyledons.

Effect of Soybean Varieties

Bhattacharya (4) studied the development of *E. cautella* larvae on 39 cultivars and lines of soybean and found that, while some cultivars could not support the development of this insect, others allowed up to 44 percent successful development. We assume that moisture content and seed coat integrity was uniform throughout the range of cultivars tested. Kapoor and co-workers (13) reported that damage of *E. cautella* to soybean grain was correlated to the thickness of the seed coat of different cultivars.

Ten soybean cultivars were used to test their nutritive value to the almond moth. To eliminate the possible effect of seed coat differences, these seeds were separately ground in a blender to pass through a 40-mesh screen. To the ground soybeans we added small amounts of water. The wet flour was stirred until a dough was formed. Small cylindrical pellets were prepared by pressing the dough through a syringe without a needle.

The different cultivars of soybeans had no effect on the duration of the larval stage; the average larval period ranged from 38 to 43 days. These soybeans, however, did have an effect on the pupal weight. The pupal weights could be grouped into three categories (1) high pupal weights (> 4.6 mg) were obtained with larvae fed "Clay" and "Hark" soybeans; (2) intermediate weights (3.7 to 4.0 mg) with larvae on "Bragg," "Corsoy," and "Clark 63," and (3) low weights (< 3.5 mg) with larvae on "Altona," "Cutler 71," "Amsoy 71," "Wayne," and "Williams" (Table 4).

Table 2. Survival to the Pupal Stage, Duration of Larval Stage and Weight of E. cautella *Larvae Reared on Soybean Cotyledons Ground to Different Particle Sizes*

	Particle size (mesh)[a]					
	> 10	10-20	20-30	30-40	40-50	< 50
Moisture content (%)	11.7	11.9	11.9	11.7	11.1	10.7
Number surviving from 30 eggs						
Male	8	8	12	7	7	10
Female	6	8	2	3	8	7
Days in larval stage	52.5	55.4	49.4	48.0	56.0	48.4
Average fresh weight (mg)[b]						
Male	11.2	11.5	11.8	12.0	11.4	11.8
Female	15.5	15.8	15.1	16.1	15.9	15.4

[a]U.S. standard screens.
[b]None of the differences observed were statistically significant at P = 0.05.

Table 3. Survival and Mean Fresh and Dry Weights of E. cautella *Larvae Reared for 30 Days on* Diaporthe phaseolorum *var.* sojae *Infected and Healthy Soybean Seeds, Cultivar "Bragg"*

Soybean	Moisture content (%)	Total survival out of 50 larvae	Average fresh weight (mg)[a]	Average dry weight (mg)[a]
Infected seed				
Cracked	10.1	34	5.9b	1.7b
Whole	10.1	16	5.0b	1.5b
Healthy seed				
Cracked	11.1	7	1.4a	0.4a
Whole	11.5	0	...	...

[a]Values followed by the same letter are not significantly different at P = 0.05, by Duncan's Multiple Range Test.

Table 4. Development of E. cautella *Larvae Fed on Pellets Made from Different Cultivars of Soybeans*

Soybean variety	Maturity group	Total survival to pupa from 50 larvae	Days in larval stage	Pupal dry weight[a] (mg)
Williams	III	22	42.8	2.91a
Wayne	III	19	43.6	3.32ab
Amsoy 71	II	22	42.6	3.38ab
Cutler 71	IV	19	41.1	3.47ab
Altona	00	31	41.2	3.50ab
Clark 63	IV	23	38.3	3.71a
Corsey	II	25	42.6	3.93b
Bragg	VII	25	39.6	4.04bc
Hark	I	22	40.7	4.62cd
Clay	0	21	39.2	4.87d

[a]Values followed by the same letter do not differ statistically at P = 0.05.

Effect of Simulated Stinkbug Injury on Infestation of Soybeans by *E. CAUTELLA*

Kapoor and co-workers (13) reported that *E. cautella* oviposited on soybean pods in the field prior to harvest. Todd and Womack (19) observed that soybean seeds damaged by stinkbugs in the field were more easily infested by stored grain pests. To test the possible effect of damage to seeds in the field on susceptibility to *E. cautella*, an experiment was conducted using artificial punctures in soybeans kept within cages in the field. We found that the almond moth did not infest soybeans under the conditions of the experiment. Neither punctured nor nonpunctured seeds presented live larvae or signs of almond moth injury.

Parallel experiments were also conducted in the greenhouse. Eggs or newly hatched larvae were placed on soybean pods so that four treatments were obtained: (1) eggs on punctured soybean pods; (2) eggs on split soybean pods; (3) newly hatched larvae on punctured soybean pods; and (4) newly hatched larvae on split soybean pods. No infestation was detected 20 days after release of the insects. These experiments, although inconclusive, suggest that infestation in the field probably contributes very little to overall infestation. From a practical point of view one should be mostly concerned with infestations postharvest, rather than preharvest.

Effect of Soybean Trypsin Inhibitors and Saponins

Trypsin inhibitors and saponins are present in soybeans in rather high concentrations. These factors are known to interfere with normal growth and development of animals. Growth retardation due to the ingestion of trypsin inhibitors was shown in rats (9, 15), mice (21), and chicks (11). In insects, the addition of the crystalline soybean trypsin inhibitor to diets failed to cause any effect on larval growth of *Tribolium confusum* (16) or *Callosobruchus chinensis* (1).

Saponins did not impair growth of chicks, rats, or mice but caused slight growth retardation in *Tribolium castaneum* (12). They were highly toxic to *Sitophilus oryzae* (18), producing 100 percent mortality within three weeks when 0.5 percent of soybean saponin was added to wheat. It was also reported that *Callosobruchus chinensis* could not complete development in the presence of soybean saponin extracts (2).

Incorporation of 0.1 and 1.0 percent of either trypsin inhibitor or trypsin inhibitor type II S to a standard medium failed to show effects of either larval mortality or mean larval weight after 16 days of trial (Table 5). Soybean saponins at the rates of 0.1 and 0.5 percent had no effect on larval mortality, but the higher rate (0.5 percent) delayed larval growth.

Table 5. Survival and Average Weight of E. cautella *Larvae Reared for 16 Days on the Standard Rearing Medium Containing Soybean Trypsin Inhibitor, Trypsin Inhibitor Type II S, or Soybean Saponin*

Growth inhibitor	Dosage (%)	Total survival from 50 larvae	Average fresh weight[a] (mg)
Trypsin inhibitor[b]	0.1	42	16.02b
	1.0	43	15.77b
Trypsin inhibitor II S[c]	0.1	45	16.11b
	1.0	45	14.76b
Soybean saponin[d]	0.1	39	14.16b
	0.5	43	6.53a
Control[e]	...	4?	16.17b

[a]Values followed by the same letter are not significantly different at P = 0.05.
[b]Purchased from Aldrich Chemical, Inc., Milwaukee; 1 mg of the product inhibits 1.8 mg of trypsin.
[c]Purchased from Sigma Chemical Co., St. Louis, Missouri; 1 mg of the product inhibits 1 mg of trypsin.
[d]Extracted from raw soybeans according to the procedure of Birk et al. (5).
[e]Control medium formulated following Boles and Marzke (6).

OTHER STORED-PRODUCT INSECTS

Few other stored-product insects have been reported to develop on soybeans and even those only under special conditions. Todd and Womack (19) observed that soybean seeds damaged by stinkbugs in the field were more easily infested by the cigarette beetle, *Lasioderma serricorne*. *Tribolium castaneum* and *T. confusum* multiplied slowly on cracked soybeans but could not survive on whole soybeans (14), as we have shown here with the almond moth. The bruchid beetle, *Callosobruchus chinensis*, is a serious pest of several legume seeds but reportedly could not develop on soybeans. Applebaum et al. (2) attributed the inability of *C. chinensis* to develop on soybeans to the saponin content of the seeds.

CONCLUSIONS

Healthy soybean seeds seem to be very adequately defended against attack by most potential pests of grains in storage. Problems arise when the integrity of the seed is violated either before or after harvest. Seed that has been injured in the field by insect pests or diseases is more vulnerable to additional damage in storage. Seed that has been mishandled at harvest, in transit to storage bins, or in storage is also more likely to become more susceptible to insect pests in storage. Finally, moisture content is likely to be the ultimate limiting factor. The almond moth and most stored-product insect pests seem to be incapable of developing in an environment kept below 13 percent RH.

The mechanisms of soybean seed resistance to insect pests have not been totally elucidated. The seed coat represents a first line of defense, but it is unclear whether the coat acts only as a mechanical barrier or whether it contains allomones. The seed itself has at least two types of allomonal compounds, in the protease inhibitors and in the saponins. The action of the former against insects is questionable on the basis of current evidence. Saponins or their glucosides seem to produce typical antibiotic symptoms. Breeding programs oriented to changing the chemical composition of grain would be well advised to carefully weigh the possible change in susceptibility to insect pests.

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Plant Spacing in Soybean Production

HARRY C. MINOR

Cultural practices, narrowly defined, encompass only a small number of the practices employed in soybean production. However, they interact with most other manipulations that influence the availability of required factors to the plant.

Photoperiodic control of soybean flowering and maturity is reasonably well understood and is an important determinant in the adaptation of a particular cultivar to a location or cropping system. In short-day environments, most improved cultivars developed in the temperate zones show little response to the fluctuation in photoperiod encountered and have relatively constant, although shortened, life cycles. The performance of these materials is markedly influenced by the management to which they are subjected.

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

To consistently achieve adequate plant stands, good quality seed must be available. Particularly under conditions of seedbed stress, it is not easy to compensate for poor seed quality by adjustments in seeding rate.

PLANT SPACING AND SOYBEAN YIELD

Soybean yields have increased gradually as the result of cultivar improvement and better management. While cultivars can be improved still more, much of the yield potential available in existing cultivars remains to be exploited through the application of appropriate management practices.

Whigham et al. (23) investigated in the tropics the effects of several environmental and management variables on site variability in yield. The mean level of yield achieved (2,034 kg/ha) was similar to that usually achieved in temperate regions. Environmental variables (altitude, latitude, day length, maximum temperature, and minimum temperature) were found to be only half as important as management variables (amounts of N, P, K fertilizer applied and site nodule number, nodule dry weight, and plant population) as determinants of yield.

An important aspect of soybean management is plant spacing. This management variable can be readily manipulated by row spacing and/or plant population. Shibles and Weber (17) found that rate of dry matter production was a linear function of the percentage of solar radiation intercepted. Time to 95 percent interception was a function of population, requiring 58, 60, and 71 days for populations of 43, 77, and 128,000 plants/ha spaced in an equidistant planting pattern. In subsequent work, they found that D_{95} occurred earlier in the season with higher populations or narrower row spacings. Yield tended to be highest in those plant spacing combinations that gave the most rapid light interception, except at very high populations where, possibly, lodging prevented full transformation of light energy into harvestable product. The responses to plant population and row spacing observed throughout the soybean growing areas of the United States can be largely explained in terms of solar radiation interception and the growth type of the cultivar used.

Cultivars grown in the southern United States are determinate in growth habit. They complete essentially all their vegetative growth by the time flowering begins. Early season temperatures are warmer in the south than in more northerly areas, and soybeans in 90 to 100 cm rows make sufficient growth to develop a closed canopy by the time flowering begins. Under these conditions, yield is stable over a range of populations, and the crop is relatively unresponsive to row spacings closer than 100 cm. Johnson and Harris (8) found that for Bragg, an optimally adapted cultivar at their location, significant yield responses were not obtained for increases in population above 6.6 plants per

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meter in 91 cm rows (72,000 plants/ha). Two early and one late cultivar required 26 plants per meter of row to produce maximum yields. No yield reductions resulted from populations above the optimum. Johnson et al. (9) suggested that there is little advantage of rows closer than 91 to 107 cm for full-season cultivars planted early. The advantage of narrow rows increases in late plantings.

In contrast, most cultivars grown in the northern United States are indeterminate in growth habit. Flowering begins when they have completed about half of their vegetative growth. Thus, pod production begins well before the plant achieves its full size and, in 100 cm rows, before interception of solar radiation is complete. Since the critical time for high light interception begins with the onset of flowering, yields may suffer. Under these conditions, row spacings close enough to permit full canopy closure at flowering are desirable. Row-to-row spacings of 50 to 60 cm have frequently been demonstrated to result in higher yields than when wider spacings are used (15, 21, 22). However, the yield advantage of row widths of 25 cm or less conflicts with early reports. Burlison et al. (4) and Kiesselbach and Lyness (10) 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 in the southern United States, the yield of adapted soybean cultivars in the northern areas is stable over a range of plant populations. Probst (16) reported that maximum yields of well adapted cultivars 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. (22) studied populations from 64,000 to 516,000 plants per hectare in row widths of 13, 25, 51, and 102 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. Throughout the United States, plant populations higher than the minimum required to produce maximum yield frequently are used to increase the height of the first pods and to encourage the rapid formation of a full canopy, which helps suppress weeds.

Realization of the potential benefits of narrow row spacings and high plant stands depends upon the adequacy of moisture during the growing season. Taylor (20) measured the response to row spacing during three seasons that differed markedly in moisture supply. During the wettest season (53.9 cm of rainfall), soybeans grown in 25 cm rows outyielded those grown in 100 cm rows by 17 percent. During the season with an intermediate season water supply (33.9 cm), yields tended to increase with the narrower row spacing, but differences were not significant. During the driest year (18.3 cm of rainfall) row spacing had no effect on soybean yields.

Soybean cultivars developed in temperate zones can be expected to be more responsive to row spacing and population when grown in the tropics than in their areas of origin. This results from earlier flowering and reduced vegetative development. Because the soybean is a short-day plant, it flowers only when the photoperiod is sufficiently short. As a cultivar is moved to a location closer to the equator, shorter photoperiods are encountered during the summer. Consequently, the cultivar flowers earlier than in its zone of adaptation and vegetative growth is reduced. Normally the life-cycle duration of late cultivars is reduced more than that of early cultivars. 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 cultivars will show no response to photoperiod during the preflowering stage. Variations in days to flower at different photoperiods occur largely in response to temperature differences during the preflowering stage (11). Abel (1) reported that planting under shorter photoperiods reduced the time from 50 percent flowering to maturity in a very early cultivar. Subsequent research by Lawn and Byth (11) showed that reductions take place primarily during the flowering phase. The reduction in life cycle of late-maturing cultivars planted under shorter photoperiods occurs primarily prior to flowering (7, 12, 14).

Results from Ecuador (latitude 3° S) typify the response of soybean cultivars to plant population at a tropical location. A group of 12 cultivars from the United States and four local entries were tested at populations of 100,000 and 400,000 plants per hectare and managed as recommended for the International Soybean Variety Evaluation Experiment (ISVEX). The yields of one local entry, Americana, and all cultivars 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 (Table 1). Cultivars of maturity group VII or earlier tended to respond more to the increase in plant population than did cultivars of later maturity groups. For the cultivars 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.

While the trial did not include a sufficient number of population levels to permit

Table 1. Results from Coordinated Variety Trial, Boliche, Ecuador, 1970

Cultivar	Maturity group	100,000 plants/ha Yield (kg/ha)	100,000 plants/ha Height at maturity (cm)	400,000 plants/ha Yield (kg/ha)	400,000 plants/ha Height at maturity (cm)
Pelicano	...	1796*	95**	1939	98*
Abura	...	2121**	63	2140	93
Mandarin	...	2101*	94*	2135	102**
Americana	...	1995*	66	2442	80
Improved Pelican	VIII	2080*	82	2539*	90
Hardee	VIII	1930*	28	2191	45
Bragg	VII	1400	27	2245	40
Semmes	VII	1621	21	2510	31
Lee 68	VI	1500	19	2275	32
Davis	VI	2003*	30	2999**	43
Dare	V	1528	23	2082	39
Hill	V	2030*	28	2717*	40
Clark 63	IV	1695*	39	2475	55
Adelphia	III	1893*	34	2705*	50
Corsoy	II	580	25	1323	37
Hark	I	1527	35	2241	49
Mean		1737	44	2310	57

	Yield	Height
LSD (0.05) between population means	85 kg	1 cm
LSD (0.05) between populations within a cultivar	342 kg	4 cm
LSD (0.05) between cultivars at the same population	462 kg	7 cm

Note: Trial was conducted by Eduardo Calero, Chief of Oil Crops Investigation, INIAP, at Boliche, Ecuador (latitude 3° S, altitude 50 m).

The top yielding or tallest cultivar at a location is designated by a double asterisk(**). Treatments not differing significantly from it are denoted by a single asterisk (*).

estimation of an optimum plant population, it did illustrate that the estimate of yield potential of each cultivar depended on the plant population at which it was grown. At the low population, a local entry, Abura, was the top yielding cultivar. At the high populations, an introduced cultivar, Davis, outyielded all local entries. However, Bastidas et al. (3) in Colombia (latitude 3° N) found that the optimum population for a tall, indeterminate cultivar may be less than 400,000 plants per hectare and that this population level may result in a yield reduction. Conversely, cultivars of the earliest maturity groups may not have produced their maximum yields at 400,000 plants per hectare. However, this test, and many others that have compared "early" soybean cultivars with those that make more vegetative growth in the tropics, clearly demonstrated that a large biological yield (big plants) does not guarantee a large economic yield.

The effects of row spacing also are accentuated when cultivars that make limited development are grown. Silva et al. (19) showed a consistent trend for increased yield as row spacing was decreased from 102 to 51 cm in twelve monthly plantings in Puerto Rico (latitude 18° N). In research conducted in central India (latitude 23° N), Minor (13) found that the effects of row spacing increased as planting was delayed. 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 suggest that rows less than 30 cm apart might have further increased yield. Optimum plant population was largely independent of row spacing.

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 Brazil (Neumaier and Minor, unpublished). Several combinations of planting date, cultivar, and plant population were studied with and without application of recommended amounts of lime and fertilizers. Fertilization increased the yield of soybean 660 kg per hectare (33 percent). The yield response to fertility was similar for each date of planting and cultivar. 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 100,000 plants per hectare could not compensate sufficiently to effectively use the area available. The responsiveness of soybeans to population increased as planting time was delayed past the optimum time. The failure of the two cultivars to use effectively 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 plant produced more pods than at higher plant populations, but as others have found (22), the spacing that produces the maximum number of pods per plant does not always produce the highest yield per hectare.

Achieving optimum plant populations may be difficult in tropical areas because high quality seeds are not always available. In addition to contributing to nonuniform and suboptimal plant populations, low quality seeds may give rise to plants with less than normal performance. Edje and Burris (6) planted seed from a single lot that had been subjected to various degrees of rapid aging and found that once equal stands were established with high-, medium-, and low-vigor seeds, yields did not differ. Assuncao (2) established stands by transplanting soybean seedlings that emerged on the fifth and seventh day after planting (classified as from high- and low-vigor seeds, respectively). High vigor was associated with more rapid vegetative growth and with an increase in soybean yield. While the two sets of results may appear to be different, a plausible explanation is available. In the first case (6), seeds of differing average vigor were planted in the field. The weaker members in each class may have been eliminated during the emergence process so that the final established populations may have been more uniform in vigor than suggested by the germination percentages of the different classes. In contrast, Assuncao (2) established populations with plants classified after emergence so that a vigor differential was ensured. Thus, if satisfactory population can be established under conditions of normal seedbed stress, little difference in yield due to seed quality should be expected. However, there is considerable evidence that emergence of seedlings from low quality seed lots is quite unpredictable under stress conditions (Table 2). As seeds of a single lot lost viability as a consequence of "rapid aging" (5), the difference between germination percentage in the laboratory and emergence in the field increased so that nearly nine times as much seed having 46 percent germination as 96 percent germination was required to establish similar plant stands.

Table 2. Germination and Emergence of Soybean Seeds after "Rapid Aging" for from 0 to 16 Days

Rapid Aging (days)	Germination (%)	Emergence (%)
0	96	88
4	94	81
8	88	60
12	81	37
16	46	10

CONCLUSION

Appropriate management is a prerequisite to achievement of the potential soybean yield in any environment. Manipulation of plant spacing is an important aspect of management as it impacts upon how effectively the crop intercepts solar radiation. Later-maturing and/or faster-growing cultivars develop a complete canopy over a wider range of plant spacings than do earlier-maturing cultivars and tend to be less sensitive to management. However, production of biomass is often poorly associated with final grain yield and many short, early-maturing cultivars produce high yields when managed appropriately. With respect to plant spacing, this includes increasing the number of plants per unit of land area and decreasing the spacing between rows until enough plants are established to give complete ground cover during pod-fill.

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DISCUSSION

Chin Ling Wang: Which soybean type--Jupiter or Hardee or Clark 63--is more promising in the tropical area? Under what conditions can Clark 63 types be successfully cultivated?

H.C. Minor: A cultivar should be selected to fit within the available growing season. Maturation before the rains end may result in poor seed quality; maturation much after the rainy season is over may lead to low yields. Thus, Clark 63 may find a place in short seasons in the tropics. Both Jupiter and Hardee will require a longer growing season and will, in general, be easier to manage.

A. Sajjapongse: What kind of spacing and plant population density would you recommend to farmers in tropical areas as compared with temperate zones?

H.C. Minor: The most important factor in each case is sunlight. A sufficient number of plants should be used in rows so spaced that light interception will be complete by the time flowering begins. The population and row spacing to recommend will depend on the growth characteristics of the variety being considered.

E.A. Kueneman: Although I agree that management practices are often largely responsible for variability in yields, your example that nodule mass was correlated with yield is misleading because it suggests the nitrogen fixation is limiting. Large plants (for whatever reason) will have large root systems and more nodules. I would guess that an equally significant correlation would have been found between leaf area and yield. We must be careful how we interpret results of our international yield trials. If we want to find out if nitrogen is limiting, we should design experiments accordingly.

H.C. Minor: The factors mentioned are interrelated. Growth conditions that favor nodule development also favor rapid early growth and, assuming continued favorable conditions, high yield. In the tropics, high yields are seldom observed under situations where nodulation is not occurring. Yet there is no doubt that until appropriate experiments are designed and conducted, the closeness of the interrelation will remain conjectural.

Flavia Kabeere: Emphasis should be put on depth of sowing since shallow-sown seeds are usually washed away by heavy rains, and the seeds are exposed to birds that eat them, thus reducing the would-be stand.

Effect of Temperature on the Germination of Soybean Seeds in the Low Humid Tropics

B.N. EMERSON

Soybeans are a relatively new crop with an exciting production potential in most tropical regions. However, constraints like stand establishment limit the cultivation of soybeans in the tropics. Many factors influence stand establishment in the field. Under tropical and subtropical conditions, high soil temperature has been cited as a factor contributing to poor stand establishment (15, 16, 18). In many soybean growing areas of the world, a soil temperature of 30° C, the approximate optimum for soybeans (5), may be near the mininum observed during the planting season. Maximum soil temperatures in these areas frequently exceed 40° C (14, 15).

The first experiments with soybeans in Sri Lanka were conducted in the late 1940s. At that time, soybeans were unable to compete with other pulses, such as green gram and cowpea, and no substantial attention was given to the crop until recently (13). However, with the introduction of improved cultivars through the Soybean Development Program (funded by UNDP/FAO) and the technical assistance from the International Soybean Program (INTSOY) that goes as far back as 1973, it was found that soybeans do well at most locations, provided that an adequate number of seedlings emerge and optimum plant populations are established (13, 19).

LITERATURE REVIEW

The most serious problem in soybean production in Sri Lanka is related to seed quality. Difficulties with stand establishment can be attributed to several aspects, such as: (1) environmental conditions during seed production; (2) environmental conditions during storage; and (3) environmental conditions during germination and emergence. Poor seed quality and viability may be experienced when the soil moisture at seed-filling stage, weather conditions at harvest, method of threshing, temperature during drying, and method of storage are suboptimal (15, 18). Poor emergence results when seeds are affected by adverse soil conditions and soil- or seedborne pathogens. Low quality seed can contribute to a stand reduction of 50 percent and a yield reduction of as much as 30 percent (1).

In Sri Lanka, soil temperatures are above optimum at the time of sowing, and this tends to inhibit germination. Furthermore, sowing time coincides with the onset of the monsoonal rains; crusting results if the soil surface dries; and seedling emergence is hampered. However, if the surface remains moist at the time of emergence, germination may be high.

Numerous studies have been conducted to establish the relationship between temperature and seed germination (5, 8, 21). These investigations established cardinal points for the germination of seeds and showed that there is a range of temperature over which germination percentages are similar (5, 21). However, within the temperature range resulting in near maximum germination, the higher temperatures result in more rapid germination.

There are differences, however, in the temperatures reported to be most favorable for germination of specific crops. This may be due to the difference in the definition of "optimum temperature" and "germination" by different workers. "Optimum temperature" is defined as the temperature or temperature combinations that result in maximum germination in a minimum time (5), and "germination" is defined as the emergence and development from the seed embryo of those essential structures that, for the kind of seed in question, are indicative of the ability to produce normal plants under faorable conditions (3).

Wilson (22), studying the optimum germination temperature of wheat (*Triticum vulgare*), soybean, and oat (*Avena sativa*) seeds, reported little difference in the germination percentages of soybeans at 10°, 15°, 25°, and

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30° C and suggested an optimum of 25° C for soybean seed germination. However, optimum temperature for germination of soybean seeds differs by cultivar or other factors (11). Edwards (8) reported the optimal temperature range for germination of Black Eyebrow seeds was between 33° and 36.5° C.

In studying the effect of temperature on seed germination of three cultivars at constant and alternating temperatures within the range of 5° to 40° C, Aquino and Bekendam (2) found that, in terms of germination percentage and development of secondary roots and primary leaves, the optimum temperatures were 30° C and 20° to 30° C. At 40° C, a high percentage of the seeds decayed. Delouche (5) also reported 30° C to be the optimum temperature for soybean seed germination. White et al. (20), however, obtained emergence with Amsoy at 40° C.

Hatfield and Egli (12) studied the effect of temperature on the rate of soybean hypocotyl elongation and field emergence. They found that the rate of hypocotyl elongation was a function of temperature and length. They also observed that the time taken for the hypocotyl to reach a length of 5 cm decreased as the temperature increased from 10° to 30° C, and seeds did not germinate at 40° C.

Researchers in West Africa found that the emergence of Kent seeds was delayed by about a day when they were exposed to 40° C for a period of 5 to 8 hours per day, although the final emergence was not significantly affected (14).

Seedborne microorganisms affect germination and stand establishment of soybeans. *Aspergillus flavus* (7), *A. mellus* (9), and *Bacillus subtilis* (17) develop more rapidly at high than at low temperatures and have been associated with decreased germination of soybean seeds at 30° C. *Pseudomonas glycinea*, a bacterium with a temperature optimum of 24° to 26° C, also has been shown to reduce emergence of soybean seeds at 35° C (16, 20).

Emerson and Minor (11) evaluated 289 soybean genotypes from the U.S. Department of Agriculture germplasm collection at constant temperatures of 32° and 38° C. They found that 48 genotypes germinated equally well at the two temperatures. The mean germination of the 48 genotypes was 84 percent and 69 percent at 32° and 38° C, while the mean germination percentages for the 289 genotypes was 82.6 percent and 23.4 percent at 32° and 38° C, respectively. Hypocotyl elongation was reduced at 38° C.

Emerson and Minor (11) also found that germination at a high temperature depended upon the quality of seeds tested. A quality differential was obtained by harvesting at maturity and three weeks afterwards. Mean germination at 32° and 38° C was 93.6 percent and 67.9 percent, respectively, for the first harvest and 77.9 percent and 43.5 percent, respectively, for the second harvest. Thus, the mean germination of seed harvested at maturity exceeded by 20 percent that of seed harvested three weeks later. Differences between genotypes in their tolerance to high temperatures were detected, and a rapid decline in germination was observed when seeds were subjected to delayed harvest. This is consistent with the findings of Ellis and Sinclair (10), who reported that a delay in harvest results in loss of viability. An increase in temperature caused a greater reduction in germination of delayed harvested seeds than of seeds harvested at maturity. This is consistent with the findings of Byrd and Delouche (4) and Delouche and Baskin (6), who reported that, as seeds lose viability, their susceptibility to stress increases.

Since there are differences within genotypes in tolerance to high temperatures, a confidence interval drawn about the mean of the higher temperature tested was used to identify the genotypes that have above average tolerance to high temperatures. Six of the 34 genotypes were classified as having such tolerance to high temperature.

The investigation reported in this paper was carried out to identify genotypes that are tolerant to above optimum temperature during germination.

Experiment 1

In this experiment, nine advanced generation genotypes were evaluated with Hardee, Pb-1, and Nuwara Eliya Local as standards at alternating temperatures of 20° and 30° C, with 16 hours at 20° C, and at a constant temperature of 38° C. All seeds were produced during Maha 1978-79 at the Agricultural Research Station, Kilinochchi. The lines were planted on 15 January 1979 and harvested at maturity. Following harvest, the seeds were sent to the Central Agricultural Research Institute, Gannoruwa, Peradeniya, and stored in cold stores at 10° C and 45 percent RH until commencement of the storage treatment on 21 June 1979.

At the commencement of the storage treatments, half of the seeds were removed from cold storage and stored at room temperature at the Agricultural Research Station, Maha-Illuppallama. During the storage period, the maximum and minimum temperature ranges were 26° to 35° C and 16° to 26° C, respectively. The mean RH was 68.2 percent. Half of the seeds were retained in the cold stores.

The experiment was designed as a randomized complete block with a split-split plot arrangement of treatments and five replications. Replicates were planted at monthly intervals, and the replicate number indicates storage time after commencement of the experiment. Plastic boxes were filled to approximately 2.5 cm from the top with sterilized sand and placed in a germinator at 38° C. Twenty-four hours were allowed for temperature stabilization before planting. The temperature was automatically controlled within ± 1° C. Seventy-five captan-treated seeds were planted in sterilized sand. The number of emerged seedlings was recorded on the seventh day. All seedlings were carefully examined for secondary root development. Seedling length measurements were taken on 15 seedlings on the same day.

Mean germinations of the twelve genotypes tested were 69.2 percent at alternating temperatures of 20° and 30° C, and 44.8 percent at a constant 38° C. As the temperature increased, the number of abnormal seedlings and dead seeds increased and hypocotyl elongation was reduced. This is in agreement with the earlier findings of Emerson and Minor (11). While temperature accounted for 22.6 percent of the total variation, genotype and storage accounted for 25.9 percent and 18.0 percent of the total variation, respectively.

All genotypes were significantly better in their germination at alternating temperatures of 20° and 30° C than at a constant 38° C. However, germination of 30120-49-3 was significantly better than the control Pb-1 at 38° C. The genotypes 49-38-1, 49-20, and 30090-1-8 germinated as well as Pb-1 at a constant 38° C (Table 1).

The mean germinations of the twelve genotypes stored at Gannoruwa in the cold room and at Maha-Illuppallama at room temperature were 61.6 percent and 52.4 percent, respectively. Six of the twelve genotypes stored as well at room temperature at Maha-Illuppallama as in the cold room at Gannoruwa. The germination of 30120-49-3 was significantly better than Pb-1, even when stored at room temperature. The genotypes 49-20, 49-38-1, and 30090-1-8 germinated as well as Pb-1 when stored at room temperature (Table 2).

Under the standard germination test (20°/30° C), the mean germination of 70 percent was maintained up to 165 days after harvest. But when the germination was tested at 38° C, the 70 percent level was maintained only up to 75 days after harvest (Table 3). The regressions between number of days of storage and germination are shown (Fig. 1). The regression coefficients (0.0379 and 0.1083) for the standard germination test were not statistically significant. The regression coefficient of the slope for the germination test at 38° C gave values of 0.3476 and 0.495, which were significant at 1.0 percent probability, showing a sharp decrease in germination with an increase in storage time beyond 75 days after harvest.

Table 1. Germination Percentages and Classification of Soybean Genotypes for Response to High Temperature

Genotype	20°/30° C	38° C
Above-average tolerance	percent	
30090-1-8	82.3	57.2
49-38-1	80.6	60.9
30120-49-3	89.6	66.5
49-20	73.7	59.8
Pb-1	85.2	54.2
Intermediate tolerance		
30120-49-2	64.6	38.9
49-2	71.3	39.7
71-41	63.6	40.8
Nuwara Eliya Local	59.0	38.3
Below-average tolerance		
49-1-1	45.8	26.1
PK-73-217	52.1	35.1
Hardee	62.4	20.6
Mean	69.2	44.8

Note: L.S.D. to compare a genotype at two temperatures = 9.2. L.S.D. to compare two genotypes within a temperature = 9.4.

Table 2. Percentage Germination of Soybean Seeds Stored at Room Temperature at Maha-Illuppallama and in the Cold Room at Gannoruwa

Genotype	Gannoruwa	Maha-Illuppallama
30090-1-8	76.8	62.7
30120-49-2	57.8	45.7
49-1-1	39.4	32.4
49-38-1	74.8	66.8
30120-49-3	79.4	76.6
49-2	57.9	53.1
49-20	64.2	69.3
71-41	63.3	40.9
PK-73-217	54.5	32.6
Pb-1	74.1	65.2
Hardee	34.4	48.6
Nuwara Eliya Local	62.4	34.8
Mean	61.6	52.4

Note: L.S.D. to compare a genotype at two storage conditions = 10.7. L.S.D. to compare two genotypes within a storage condition = 9.4.

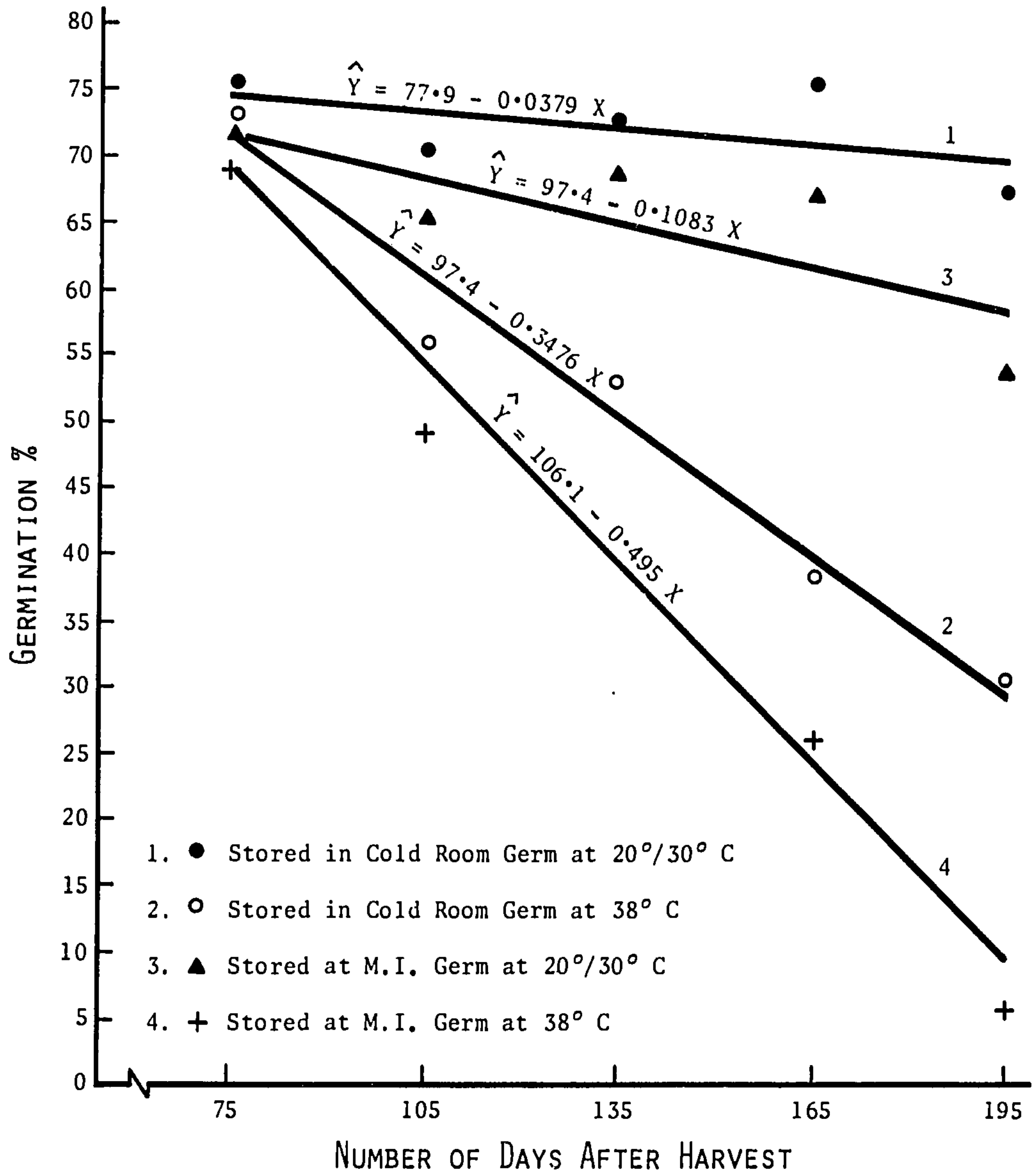

Figure 1. Rate of decrease in germination at different temperatures and storage conditions.

Table 3. Percentage Germination of Soybean Seeds at Different Storage Intervals

Temperature	Period of storage (number of days after harvest[a]) 75	105	135	165	195
			percent		
Gannoruwa					
20°/30° C	76.2	70.7	73.1	76.1	67.7
38° C	73.9	56.3	52.9	38.5	30.5
Maha-Illuppallama					
20°/30° C	71.7	65.1	69.3	67.5	54.2
38° C	69.2	49.0	45.3	26.2	6.3
Mean					
20°/30° C	74.0	67.8	71.2	71.8	61.0
38° C	71.6	52.7	49.1	32.3	18.4

[a]The seeds were stored in the cold room (10° C and 45% RH) for a period of 45 days from harvest to the commencement of this experiment.

This is consistent with the finding of Byrd and Delouche (4), who reported that, as seeds lose viability, their susceptibility to stress increases. Emerson and Minor (11) reported that germination of soybean genotypes was significantly reduced at 38° C when the seeds were stored for 15 to 18 months.

Experiment 2

This experiment was also designed to evaluate the advanced generation genotypes for tolerance to high temperature. The seeds used were produced at the Agricultural Research Station, Maha-Illuppallama, during Maha 1979-80 and harvested in mid-February 1980. The seeds were treated with captan and stored at Maha-Illuppallama at room temperature. The experiment was designed as a randomized complete block with a split-plot arrangement of treatment and three replications. The two temperatures were the whole plots, and the genotypes were subtreatments. The temperatures used were the same as in the previous experiment (20°/30° C and constant 30° C).

The mean germinations of 20 genotypes were 68.1 percent and 43.3 percent at 20°/30° C, respectively (Table 4). The two genotypes 30090-1-8 and 30120-49-3 were as consistent in their performance as in Experiment 1 and germinated as well at 20°/30° C as they did at 30° C. Four other new genotypes and Nuwara Eliya Local also germinated equally well at both these temperatures.

A confidence interval was drawn about the mean germination at 38° C and was used to divide the genotypes into three classes.

Table 4. Germination Percentages and Classification of Soybean Genotypes for Response to High Temperature

Genotypes	20°/30° C	38° C
Above-average tolerance	*percent*	
30090-1-8	92.0	74.0
30120-49-3	88.0	70.6
F 73-14-1-8(2)3(3)2	95.3	78.6
PM-78-1-5-8	92.0	76.6
Nuwara Eliya Local	96.0	88.0
PM-78-2-5-6	93.3	85.3
PM-78-2-5-20	96.6	86.6
Intermediate tolerance		
UPSL-216	71.3	25.3
49-38-1	57.3	30.6
49-20	57.3	24.0
74-41	48.0	26.0
PM-2-5-1	80.0	40.6
PM-78-6-5-4	75.3	39.3
PM-78-6-5-13	88.6	48.6
Pb-1	58.0	24.0
Below-average tolerance		
M(534 x 538)F7-8-12-7	73.3	20.60
PM-78-6-5-22	40.0	7.33
Bossier	14.0	0.66
Hardee	12.6	1.33
Improved pelican	86.0	18.60
Mean	68.09	43.30

Note: L.S.D. to compare a genotype at the two temperatures = 33.5.

The five genotypes 30120-49-3, 49-38-1, 49-20, 30090-1-8, and Pb-1 were classified as having above average tolerance to high temperature in Experiment 1. Hardee and 49-1-1 were classified as having below average tolerance. The other five genotypes were classified as having intermediate tolerance.

In Experiment 2, the genotypes 30120-49-3 and 30090-1-8 were again classifed as having above average tolerance to high temperature. Among the new genotypes tested, four advanced generation genotypes, F 73-14-1-8 (2)3 (3) 2, PM 78-1-5-8, PM 78-2-[illegible]-6, and PM 78-2-5-20 were classified as having tolerance to high temperature. In Experiment 2, Nuwara Eliya Local was classified in the above tolerance group, while Pb-1, 49-38-1, and 49-20 dropped down to the intermediate tolerance group.

The tolerance of the four genotypes--49-20, Pb-1, 49-38-1, and Nuwara Eliya Local--varied between high and intermediate, depending on the quality of seed produced. The variable response of Pb-1 and Nuwara Eliya Local to high temperature may limit their usefulness in tropical production areas.

Seedling Lengths

With all cultivars, seedling length was significantly reduced at the higher temperature (Table 5). This is consistent with the earlier findings of Hatfield and Egli (12), who reported that the effects of high temperature during germination are manifested in decreased hypocotyl elongation. Also, there was no significant difference in seedling length of soybean genotypes at two storage conditions (Table 6).

Table 5. Mean Seedling Length of Soybean Genotypes at the Two Temperatures

Genotypes	20°/30° C	38° C
30090-1-8	25.60	8.72
30120-49-2	19.56	6.38
49-1-1	21.43	5.83
49-38-1	24.20	9.15
30120-49-3	2[illegible].93	10.17
49-2	23.85	7.38
49-20	20.46	7.25
71-41	20.27	7.32
PK 73-217	23.65	7.42
Pb-1	28.56	10.55
Hardee	18.94	4.74
Nuwara Eliya Local	22.49	8.51
Mean	22.83	7.79

Note: L.S.D. to compare a genotype at the two temperatures = 0.85. L.S.D. to compare two genotypes within a temperature = 2.19.

Further, it was observed from the same experiment (data not presented) that, under standard germination conditions (20°/30° C), there was no appreciable difference in seedling length between the two storage conditions and the storage periods. However, at 38° C, there was a significant decrease in seedling length with an increase in the length of the storage period.

In tropical areas the soil temperature during certain seasons can exceed the optimum temperature for germination. Since there is a drop of 20 to 25 percent in germination at above optimal temperature, it may be possible to increase the seed rate by 20 to 25 percent. This could result in optimum plant population and, thus, increased yields.

Table 6. Mean Seedling Length of Soybean Genotypes at the Two Storage Conditions.

Genotypes	Gannoruwa (cold room)	Maha-Illuppallama (room temperature)
30090-1-8	17.62	16.70
30120-49-2	14.17	11.70
49-1-1	14.30	12.96
49-38-1	17.33	16.02
30120-49-3	18.06	17.04
49-2	17.12	14.10
49-20	14.16	13.55
71-41	12.06	15.53
PK 73-217	16.31	14.76
Pb-1	20.66	18.45
Hardee	13.38	10.30
Nuwara Eliya Local	17.29	13.71

Note: L.S.D. to compare two genotypes at a constant storage = 2.07; to compare two genotypes at two storage conditions = 3.74.

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Physical Factors Affecting Stand Establishment: Effect of Soil Temperature, Moisture, and Texture on Stand Establishment

R.B. DADSON

Successful germination and emergence of seedlings from the soil is a prerequisite in plant growth and development into a commercial crop. It is only after emergence that a seedling can interact with the aboveground environment to yield the intended product. High emergence and good stand establishment will, therefore, be necessary for high yields of soybean. In a congenial soil environment both low and high vigor seeds produce an acceptable stand. However, under stress conditions germination and emergence of all seeds are affected adversely. The critical soil factors that may induce stress are moisture, temperature, and soil texture. These factors singly or in combination have hampered the introduction of soybeans into the tropics and subtropical zones. This paper will review and offer some recommendations on practices which may be adopted to mitigate the adverse effects of soil factors. Research needed to enhance the chances of the seed to give good germination and emergence will also be indicated.

GENERAL EFFECTS OF MOISTURE

The first process in the germination sequence of events is the imbibition of water. Available soil water is, therefore, a crucial factor, determining successful germination and seedling emergence.

A seed imbibes water to a certain moisture content before germination. The seed moisture content (dry weight basis) required for soybean germination is about 50 percent, in contrast with 30 percent for corn and 26 percent for rice. Thus, soybeans require a higher moisture level, almost twice that for rice, for germination. The seed moisture content can be attained in five days from a soil with a moisture tension of not less than -6.6 bars. Soils in the tropics enter the planting season very dry and have high soil moisture tensions. The common practice of planting maize, sorghum, millet, or cowpea immediately after the first rain is suitable to these crops due to their ability to imbibe at high moisture tensions. If this practice is applied to soybeans, however, the seeds may not imbibe sufficient moisture to germinate. At a very high soil moisture tension with an inadequate moisture level leading to insufficient imbibition, the seeds will be exposed to many fungi that germinate, invade, and subsequently kill them. Thus, when soybean seeds were originally placed in an inadequate moisture environment (-8.9 bars) for 8 days and then transferred to an environment with sufficient moisture, there was a failure to germinate due to the action of fungi. This situation could be a serious threat to soybean cultivation in the tropics if seeds are planted too early in the season as is done traditionally with several food crops.

In low soil moisture situations, it appears that small-seeded soybean cultivars germinate and emerge more rapidly than the large-seeded types. In a study using seed of near isogenic lines with 100-seed weight of 9.5, 12.6, and 22.68 planted in clay soils at moisture levels of 20, 22.5, 25, 27.5 and 30 percent, respectively, Edwards and Hartwig (3) reported that there was no emergence of seedlings at 20 percent moisture. However, for each moisture level where germination occurred, the smaller- and medium-sized seeds gave more rapid emergence and a greater root development than larger-seeded lines. Since rapid germination and emergence in the field will usually reduce the hazards of obtaining a uniform stand, and no differences in seed yield were found from planting different seed sizes, it has been suggested that cultivars with average seed sizes of 9 g to 10 g per 100 seed would be useful in obtaining uniform stands under low soil moisture conditions (3, 11).

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Moisture Required for Emergence

Germinated soybean seeds seem to require less moisture for emergence. In drying soils, the seedlings seem to be protected from desiccation by osmotic adjustment to the hypocotyls. The adjustment is made by movement of solutes from the cotyledons to the elongating hypocotyl cells. This maintains a constant turgor pressure under conditions of tissue desiccation and slow but continuing growth, even at tissue water potentials as low as -9 bars (19).

Effect of Excess Water

Frequently cultivated tropical and subtropical soils lose their high inherent infiltration capacity and internal drainage under the force of tropical rainstorms. As a result of heavy downpours, structural degradation and crusting occurs, and the soils can become saturated with water for three to five days (22). Under such soil conditions, seed germination and emergence are severely hampered. Seedlings become yellow and stunted, presumably as a result of exclusion of oxygen and nitrogen from the root, which leads to a rapid decline in nitrogen fixation by the root nodules (22). When soils prone to holding excess water for long periods are drained, however, conditions are improved for increased germination and emergence (8).

Placing dry soybean seeds in wet soils reduces germination considerably as a result of imbibitional injury. This occurs because of too rapid hydration of outer cotyledonary tissue in comparison with the inner tissue, which causes a tension crack between the wet and dry tissue of the cotyledon (15,20). Owing to improper understanding of drying procedures for seed production in the new areas where soybeans are being introduced, the second season crop may be overdried in the low humidity and hot environment, causing adverse effects on germination and emergence.

In order to achieve rapid emergence, soybeans are planted at shallow depths up to 5 cm. At such seeding depths, moisture stress develops easily. According to Bowen and Hummel (1), the visible moisture front moves down inversely to the amount of water in the soil. Thus, the visible moisture front of soils with 5-percent and 7-percent moisture were found to cross the seeding depth within 6 and 28 hours, respectively, while the front for the 9-percent moisture content did not reach the seeding depth at the end of 48 hours. Under such conditions compaction of the soil was shown to increase soil moisture availability.

EFFECT OF SOIL TEMPERATURE

Soil temperature effects on germination and emergence are very important because tropical soils at the beginning of the planting season are quite high in temperature, ranging between 25° and 37° C (2) or 23.5° and 41° C. According to Hicks (14), Delouche, in 1953, reported that germination of soybeans in the shortest time occurred at a constant temperature of 30° C, with the optimum temperature being 34° to 36° C and the maximum being 42° to 44° C. This indicates that in the tropics, soil temperatures are near optimum for germination and emergence. However, recent studies indicate a genetic control of temperature-induced hypocotyl inhibition in several cultivars when they are exposed to a temperature range of 21° to 28° with inhibition being maximum at 25° C (7, 8, 12). Thus soybean cultivars that were bred for lower soil temperature regimes of temperate soils are being introduced to the tropics to be exposed to high soil temperatures that limit hypocotyl elongation. The findings on temperature effects on emergence are, however, conflicting. Stuckey (21) reported that soybeans emerged from planting depths up to 7.5 cm and at a faster rate at high temperature (32° C), contrary to the reports by Metha and Prihar (18) and from Nigeria (23) that mulching reduced soil temperature and also caused higher germination and emergence.

EFFECT OF SOIL TEXTURE

Soil texture affects germination and emergence of seedlings through its influence on moisture-holding characteristics of the soil, surface crusting, mechanical impedance, temperature, and aeration. Pore space is determined by the textural class. In loose, sandy soil there are fewer pore spaces than in clay soils, and, hence, less moisture is stored for germination, seedling growth, and stand establishment. In a study on the effect of soil water potential of two soils on soybean emergence, it was reported that plants emerged from the clay soil at a faster rate and were more normal than those from the silt loam over a wide range of soil water potentials of -0.1 to -0.7 bars (13). Since there was no apparent physical restriction to emergence at the surface of either soil textural class, the difference was attributed to a higher water content at all soil water potential levels of the clay soil.

Emergence from soil by germinating soybean and radicle elongation may be restricted by mechanical impedance of the soil as a result of soil surface crusting or soil compaction. Surface crusting arises from ponding on poorly drained soils that are subject to frequent rainstorms. The formation of dense crust has been reported to cause sparse stand establishment and no growth (6). Crust on the undrained plots could not be penetrated at maximum force (4.5 kg/cm^2). Drainage, however, reduced considerably the sizes of crust units and the force required for penetration. It consequently improved tap root formation and lateral root distribution. Germination and emergence of soybeans are also enhanced when there is adequate moisture. Thus, even as crust strength was increased, soil at field capacity was reported to have germinated and had more seeds emerged than when only 25 percent moisture remained in the soil.

In soil with high mechanical impedance, hypocotyl elongation is considerably reduced. Bowen and Hummel (1), reported that seedlings growing at 25° C could not emerge from a depth greater than 2.5 kg/cm^2, in spite of the high temperature exposure. This study indicates that, even though temperature controls growth rate of both hypocotyl and radicle, mechanical impedance up to 1 kg/cm^2 will greatly reduce hypocotyl growth.

Excessive plowing with the aim of pulverizing the large clods in soils produces small fraction size, which will have adverse effects on soil conservation. Falayi and Lal (5) reported that soil aggregate size of 2 mm or less was the most undesirable size fraction as far as run-off, erosion control, and avoidance of surface crusting were concerned. The fine soil tilth, such as less than 2 mm size fraction, also had maximum crusting problems. For runoff, erosion control, and avoidance of surface crusting, the most desirable soil aggregate size range was 10 to 55 mm. This range encouraged higher soybean emergence.

EFFECT OF MULCHING

Mulching with plant residue, soil, or gravel exerts beneficial influences on soil physical characteristics and thereby improves emergence and stand establishment.

Mulching with plant residue breaks the impact of rain drops on the soil and thereby preserves soil tilth and prevents ponding. Infiltration is improved under such conditions, and surface crusting and mechanical impedance are minimized, creating an environment conducive to high emergence and stand establishment.

Moisture availability in the seed zone has been reported to increase as a result of mulching with organic residue (2, 17) or gravel and sand (4). This is brought about by reduction in erosion and evaporation from the surface of the soil and increased infiltration and earthworm activity under the mulch (16, 17). Increases in the emergence of low quality soybean seed has been attributed to moisture conservation and reduced surface crusting as a result of grass mulch (2).

During the warm period of the day, soil temperature has been reported to be 3.5° C lower at a depth of 2.5 cm under organic mulch than under unmulched plots (2, 17, 18). In the study by Metha and Prihar (18) more rapid and greater final emergence of soybeans occurred under mulch than from bare soil. The effect was more marked in a simulated rainfall applied a day after planting. The beneficial effect of straw mulch in the absence of rainfall was attributed to a reduced maximum temperature in the seed zone as each ton of straw applied per hectare reduced the maximum soil temperature by approximately 1° C. The mulch minimized crust formation and reduced soil temperature after a rainfall. Whigham and Minor (23) cited examples where rice straw mulch is reported to have reduced temperature and improved stand establishment by about 66 percent in studies in Nigeria. In contrast to the cooling effect of plant residue as mulch, gravel mulch is reported to increase maximum soil temperature (4). This may be detrimental to soybean germination and subsequent hypocotyl elongation and stand establishment in an area of high insolation.

A most important effect of mulching is earthworm activity, which Lal (17) reported was greater under mulched than unmulched plots. Earthworms are intolerant of drought, high soil temperature, acidity, and low organic matter, and, since their presence is encouraged by mulch, they are found to be an important factor in improving porosity, structure, water intake, and soil fertility through cast production. The worms under mulch also caused low bulk density and penetrometric resistance. The two effects would be very important in obtaining high seedling emergence.

PRACTICES AND RESEARCH PROGRAMS

From the standpoint of soil physical characteristics, there are certain cultural practices that can be adopted to enhance germination and emergence of soybeans in the new areas where soybeans are being introduced.

In areas where soil moisture is limited at the beginning of the planting season, it is recommended that planting be delayed until the rain becomes more regular to ensure that ample moisture is available for imbibition, emergence, and hypocotyl and radicle elongation.

Weather records dating back several years should be studied to determine the pattern of rainfall distribution in each ecological zone. Soil moisture may be conserved by using plant residue as mulch. In most tropical zones there is a plentiful supply of crop residue after harvesting the first season crop (for example, corn, rice, sorghum, and millet), which can be used as mulch to grow soybeans in the second season.

Soils that are prone to ponding may be drained, by using either surface or subsurface drainage systems to reduce excessive moisture and subsequent crust formation when the water dries.

Temperature effects can be mitigated by the use of plant residue as mulch. This is very important in areas of high insolation.

With regard to soil texture, the fine clay soil, which may hold more moisture, may be a preferred soil for soybean production. In very loose soils, compaction of soil may assist in bringing the water closer to the seed in the seeding zone.

Where land preparation is mechanized, it is undesirable to produce a very fine tilth, which may accentuate runoff and erosion and reduce crust formation and, subsequently, emergence. Thus, excessive tillage should be avoided.

Mulching may be used to reduce runoff and erosion as well as surface crusting. Since earthworm activity is enhanced under grass mulch, the practice of mulching wherever feasible should be encouraged.

These cultural practices should be used in conjunction with high vigor seeds. Urgently needed for successful commercial production of soybeans in the tropics and subtropical zones are breeding programs that will improve the cultivars now available in their germination and emergence under stress conditions. First, highly viable seeds should be selected, using the hard seedcoat character as a selection criterion. Second, seed adaptation to high temperature will ensure that there is tolerance to high-temperature-induced inhibition of hypocotyl elongation. This will allow rapid emergence and establishment of germinated seedlings. Third, since small-seeded isogenic lines showed a higher emergence from crusted soil without yield loss compared with large-seeded lines, it will be advantageous to develop cultivars whose 100-seed weight will be about 10 gm.

SUMMARY

The main physical soil factors that influence soybean germination and seedling emergence are moisture, temperature, and soil texture. In the tropics and subtropics, moisture may be limiting or in excess. Too low soil moisture does not permit sufficient imbibition with the result that fungi present in the soil germinate and kill the seed. Excess soil moisture leads to waterlogging and ponding, which will interfere with oxygen and nitrogen availability to the seedling and cause it to turn yellow. In addition, crust formation is increased when soi dries, and, hence, there is an increase in impedance to hypocotyl emergence. When the seed moisture content at the time of planting is lower than 10 percent and the soil is wet, imbibitional injury occurs that causes germination failure.

Very high temperature in the tropics and subtropics may lead to an inhibition in hypocotyl elongation of most of the cultivars being introduced from temperate zones.

Soil texture influences moisture-holding characteristics of the soil, infiltration, runoff, erosion, impedance, aeration, and surface crusting. The fine clay soils hold more moisture and encourage higher emergence, and the loose, sandy soils hold less moisture for the seedling. Mechanical impedance due to too much compaction of soil causes reduced emergence and stand establishment of soybeans. Overtilling of the land to produce a fine tilth can lead to increased runoff, erosion, and surface crusting, which will increase impedance.

These stress conditions can be mitigated by applying plant residue as mulch. The mulch not only conserves soil moisture, increases infiltration, and reduces surface crusting and soil temperature, but it also promotes earthworm activity, which very significantly improves soil tilth and fertility and exerts a stabilizing influence on the soil.

Cultural practices and cultivar improvement that encourage higher germination, emergence, and stand establishment are suggested.

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DISCUSSION

A. Sajjapongse: Given the same amount of water, emergence from clayey soil is greater than from sandy soil. Considering the absorptive force from clay and sand for water, imbibition of water from clayey soil would be more difficult than from the sand and, hence, less seed would emerge. This is contrary to what you said. Please comment.

R.B. Dadson: Due to the small-particle size of the clay fraction, there is a higher total surface area, which permits better contact between the seed and the wet surfaces of the soil particles. Hence, there is more total available water in the clay for imbibition than from the silt loam, which does not expose as much wet soil surface for the imbibition.

P.R. Hepperly: Can the types of clay be important in determining crusting potential of soils?

R.B. Dadson: Although the different clay minerals have different moisture-holding potentials and rates of moisture infiltration, they do generally have low infiltration rates, and they are generally prone to clod formation. However, their expansion and contraction characteristics are different, and, thus, montmorillonitic soil, on crusting, also breaks up into a finer crust size at the surface as compared with kaolinitic clay soils that do not expand and contract as much.

J.R. Lockman: Far too little attention is being paid to the sowing of seed in moist soil. Simple equipment (hand-, animal-, and/or other-powered) is essential for placement of seed at the proper rate and in properly spaced lines, which also permits weeding. Banded fertilizer enables the plant to more efficiently use the nutrients added. The planter should enable the farmer to accurately place his fertilizer at the time of sowing.

R.B. Dadson: Any measure that will ensure that seeds are properly placed, so that there is not too much compaction, and that there is enhanced availability of water to the seed will also promote higher imbibition by virtue of the fact that it brings soil water to the seed. As indicated in your comment, line planting has several advantages, including the ease of band fertilizer placement.

Factors Affecting the Sowing of Planting Seeds: Land Preparation and Planting

PETCHARAT WANNAPEE

Soybeans are widely grown in many countries under weather conditions from temperate to tropical. They are also well adapted to different soil types. Soybeans are known as the miracle crop of the world, a low cost food source high in protein and in calories, especially in countries where other high-protein foods are expensive, not available, or, as in the case of meats, prohibited or restricted by religion. Soybeans are the popular substitute for those foods. Much research has been done in different fields in different countries to find out how to increase soybean yields. However, the results still do not cover everything that we need to know. Therefore, research must be continued forever, since many factors are involved and those factors are unstable, changing every day. Nevertheless, soybeans are grown year-round in many countries, especially in Asia, for food and for oil.

LITERATURE REVIEW

Land Preparation

Land preparation is necessary for soybean planting just as it is for other field crops such as cotton and corn. Good land preparation leads to high yields when appropriate cultural practices are used. Arwooth, quoted by Bowen and Hummel (1) said, "Legumes are highly adaptable as to soil conditions. However, they do produce higher yields on light to medium soils with good drainage. On acid soils and heavy clays, legumes are less vigorous as also is *Rhizobium* activity."

In developed countries, most farms are large, and land preparation and planting are done solely by machines. In developing countries, farm sizes are usually small, and land preparation and planting are done by farmers using small hand tools. Land preparation makes the land suitable for planting, helps seed germinate quickly, and helps roots of seedlings take up moisture and nutrients from the soil. Good land preparation also kills weeds in the field, helps make use of crop residues, and establishes good surface tilth to prevent soil crusting and allow water to remain in the soil as long as possible. Scott and Aldrich (13) stated that conventional seedbed preparation methods for a given locality and soil type may be safer than reduced tillage systems, but every grower should consider the changes he might make to save time and soil without sacrificing yield. In some cases it may even be profitable to take a slight yield reduction if tillage costs can be reduced enough to increase net return per acre.

Soybeans require a more moist soil than corn for germination. They cannot take on moisture from a nearly dry soil as well as corn. Soybean seed must absorb 50 percent of its weight in water to germinate, compared with only 30 percent for corn (3).

Scott and Aldrich (13) conclude that land preparation must provide requirements for seed germination and root growth and tillage for weed control, residue management, and maintaining or improving tilth. They describe the steps of land preparation as:

1. Primary tillage operations include breaking sod, burying trash and residues, killing weeds, and loosening the plow layer. The main tools are moldboard, chisel, disc plow, lister, and rotary tiller.
2. Secondary tillage follows primary tillage to firm and pack a coarse, rough seedbed, loosen a hard seedbed, crush clods, chop trash or sod and kill weeds, smooth the seedbed surface, and conserve moisture. The equipment used includes disk harrows, spring-tooth harrows, field cultivators, spike-tooth harrows, and cultipackers.

From the literature it is concluded that land preparation with heavy equipment can cause some problems with the seedbed. Use of heavy equipment, especially when land is overworked (maximum tillage), can lead to

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severe soil compaction and formation of a soil crust. These can result in poor or uneven seedling emergence.

As mentioned by Scott and Aldrich (13), the pioneer farmers never overworked seedbeds, because they did much of the work by hand. Later, when working with horses, they seldom overfitted the soil. It was only after tractor power was widely used that overfitting became common. This has not happened in developing countries because most land preparation is done by simple manual or animal methods, not with heavy equipment. Scott and Aldrich recommend the following methods for reducing tillage:

1. Mount cultivar sweeps or rotary devices on a tool bar ahead of the planter to smooth the surface and kill weeds in the row or the entire area;
2. Spray herbicide—band or broadcast—as tractor pulls the planter over the field; and
3. Harrow once, then plant either as a separate or combined operation.

Planting

In developed countries soybeans are planted by machine (planters); the distance between rows and seed are adjusted depending on yield tests done in the specific area. In many places, soybeans are planted in 90 to 100 cm rows; however, there appears to be a slight yield advantage in closer row spacing under favorable moisture conditions. Row spacings of 25 to 50 cm may increase yields 2 to 5 bushels per acre if adequate moisture is available (14).

The wide row system permits using regular cultivating equipment. Enough viable seed should be planted to get eight to twelve plants per 30 cm in drill rows for high yields that are easy to harvest. Depending on seed size, 40 to 60 pounds per acre will be required for 75 to 100 cm rows and 90 pounds per acre may be necessary where double rows or narrow rows are used.

Weeds will be more troublesome during the seedling stage when stands are thin. Also, poor stands increase losses because of difficulty in harvesting the resulting short, bushy plants with tools set close to the ground. Thicker stands are more subject to lodging if good growing conditions exist.

Seeds should be planted 2.5 to 5 cm deep with a corn or cotton planter equipped with a bean plate.

Narrow row spacings can be obtained with a grain drill by plugging certain flutes or by using newer types of unit planters.

A planting rate from eight to ten to twelve good seeds per 30 cm of row in the traditional 75 to 100 cm row is almost a universal recommendation. As row width narrows, the planting rate should be adjusted. Studies where narrow rows are used indicate that optimum populations are six to eight plants per 30 cm of row at harvest time in 75 cm rows, to six plants per 30 cm of row in 50 cm rows, three to four plants per row 30 cm in 25 cm rows. Plant population should depend on fertility level of the field, lodging resistance of the cultivar and conformation of the cultivar used (7).

CURRENT RESEARCH AND DEVELOPMENT

There are many critical factors that affect soybean seedling emergence, especially seed vigor and soil condition. With high vigor seedlings very few factors are critical, except under extreme weather and soil conditions at planting time. But with low vigor seedlings a stress of any one or more of edaphic (soil physical) conditions makes all aspects of the planting operation critical. Therefore, land preparation is very important for stand establishment of soybeans. If land preparation is good the range of planting depths will not affect the stand of seedlings and yield of soybeans. A range of planting depths will give nearly equal results in terms of yield when seed quality and seed environmental conditions in the soil are good. However, when adverse seed environmental conditions in the soil prevail due to excess moisture and/or crusting, a more shallow planting depth is favored. Conversely, when poor germinating conditions exist due to less than adequate moisture levels, a deep planting depth is better (1).

Subtropical and tropical regions are being shown to have great potential for soybean production. The potential will no doubt increase as new adaptable cultivars become available. The improvement of soybeans is still, however, in an early stage, thus there is much room for development. Technological innovation for higher production and better preservation of soybeans must be implemented to meet diversified regional conditions and requirements (2).

The advantage of 75 cm and narrower rows for soybeans were recognized during research on narrow corn row spacings. It was known, at that time, that rows 75 cm apart were not optimum for soybeans, but the convenience of 75 cm corn and soybean culture for the farmers kept soybeans in 75 cm rows for several years (16).

Throckmorton (16) has divided planting equipment (planters) into four categories:

1. Solid seeding equipment or drills;
2. Very narrow row equipment or drills and planters;
3. Narrow row equipment or row crop planters; and
4. Farmer-developed equipment.

Preliminary results on stubble planting of soybeans following the rice harvest are encouraging. Care must be taken to provide suitable weed control to promote vigorous growth. Plowless farming seems to be quite advantageous in sowing the seeds during this period (not in literature cited).

Bean production in most Asian countries is labor-intensive and takes place on small farms with field sizes that average less than 1 acre. In many of the rice-producing tropical countries, soybeans are grown in the off-season following one or two crops of rice. Since labor is adequate and yield levels low, considerable increase in land productivity is necessary. Soybean production may be entirely a hand operation in many of these countries (2).

There are three soybean-growing seasons in Thailand and other countries of Asia. In Thailand, the first is during the dry season, with planting in late December and January. Several types of land preparation are practiced:

1. The traditional method practiced by Thai farmers for many years is to dibble soybean seed among rice stubble and then to irrigate the field. After five or six days the seeds germinate and start to grow. The field is then irrigated every seven to ten days, depending on soil type. No weed or pest control is practiced. With this method, yields are low (Table 1).
2. The second method now being developed is to cut the rice close to the ground level at harvest and burn the remaining straw. After one or two days, soybean seeds are dibbled among the stubble and then covered with ashes or manure. Before or after planting, the field is irrigated. Two or three weeks after the soybeans emerge, some farmers do weeding and apply fertilizer and pesticides. Farmers dibble soybean seeds in holes to achieve the desired spacing.
3. In the third method, farmers plow the land before planting. Weeding, fertilization, and pest control are practiced.

The second growing season is the rainy season. Most rainy season soybean production is done on upland areas as a rainfed culture.

Table 1. Agronomic Data for the Methods of Weed Control and Soil Preparation for Soybeans Grown in Paddy Field, Chainat Field Crop Experiment Station, Dry Season, 1977

Treatments	Yield		100-seed weight (gm)	Height (cm)	Pods/ plant	Weed score
	gm/m8^2	kg/rai				
Main plot (A)						
Rice stubble	668	133.6	17.72	31.4	14.7	3.44
Straw burning	657	131.4	17.50	34.6	15.7	3.56
Tillage	793	158.6	17.91	41.1	20.3	3.44
Ridging	960	192	18.79	41.3	20.6	4
L.S.D. 5%	166.51	...	0.85	1.71	2.87	...
L.S.D. 1%	239.24	...	1.22	2.46	4.12	...
C.V. (%)	27	...	5.9	5.7	20.1	...
Subplot (B)						
Mulching	919	183.8	17.86	37.8	19	4.38
Hand weeding	830	166	18.45	39	19.3	1.94
Alachlor	691	138.2	18.46	37.1	17.3	3.50
No weeding	638	127	17.15	34.5	15.8	4.63
L.S.D. 5%	88.69	...	9.9	1.93	1.82	...
L.S.D. 1%	118.96	...	1.2	2.58	2.44	...
C.V. (%)	16	...	6.9	7.2	14.2	...
A/B	NS	...	NS	NS	NS	

Source: Nart-Triphop, 1977(8).
Note: Moisture content is 12 percent; soil texture is clay loam, Chainat series.

Land preparation is by manual or animal labor if the farm size is not over 5 acres. At the present, because the time lag is critical and both manual and animal labor are short, small farmers use small tractors designed locally for plowing and weeding. On medium to large farms (more than 5 acres), land preparation is done by tractors hired from other farmers or from merchants. Soybeans are planted solely by hand. About two-thirds of Thailand's soybeans are produced in this season. After soybeans are harvested in August or September, the land is planted to other crops such as cotton, corn, and green and black gram.

In the northern province of Sukothai, farmers plant soybeans in April or May, in rows spaced about 1 m apart. Cotton is grown between the soybean rows, as intercropping. Soybeans then are harvested in July or August when peak rainfall occurs, so yield is low and seed germination and storage capability are much affected.

The third growing season is at the end of the rainy season, with planting around August or September in Thailand. Land preparation also is done by tractor, but because the land is wet it cannot be well-prepared. Therefore, seeds are sown and covered with soil at the time of plowing. Soybean seeds produced in this season have high germination and storage capability due to being harvested in November or December, when there is no rain and climatic conditions are favorable. This growing season is limited to small areas where rain is not heavy in August and September (7).

In Thailand, the soybean yields vary with different types of land preparation:

1. Land tillage and riding by lifting the soil surface above ground level gives the highest yield;
2. Land tillage gives the second highest yield; and
3. Dibbling soybean seeds in rice stubble, whether the straw was burnt or not, gives the lowest yield.

CONSTRAINTS TO EFFICIENT PRODUCTION

In tropical regions, shortage of high quality seeds is one of the problems in promotion of soybeans. With seeds of low quality seed, it is difficult to get good stands. Time lost for land preparation delays harvest with problems of rain. Planting equipment appropriate to the work of the small farmers is a necessity. Farmers need to improve their practices in order to increase soybean production to meet the world demand. Research work should be concentrated in the areas that can help farmers to cope with their present problems. The results of research should be available to farmers, especially, low income farmers. In the past, research has been concentrated on high cost machines for the rich farmers.

The cost of research can no doubt be recovered most quickly by including it as a small part of the sale price for the high price machines. Unfortunately, these research and design procedures do not help the less developed countries that can only afford low-cost hand and animal technology. Creating something other than the largest, most complete machine has not been considered very exciting or even worthwhile (2).

Sound development must build upon rather than destroy farmers' traditional techniques (9).

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DISCUSSION

J.A.G. Joshi: What is your opinion about the concept of no tillage or minimum tillage for soybean cultivation? Can this work under tropical conditions?

P. Wannapee: In light soil and good drainage, there is no need to have tillage. In the case of heavy soil types, there should be some tillage in order to break the soil crust in order to facilitate sowing of seeds and seedling emergence.

Purity and Germination Testing of Soybean Seeds

ERLINDA PILI-SEVILLA

High quality seed is essential to the increased and improved production of soybeans. There are many attributes of seeds that affect quality and, subsequently, the stand and establishment of soybeans in the field (8, 9). Germination and purity of seeds are two important factors affecting field performance. Among the tests available for assessing seed quality, the germination test with its limitations still remains the seed industry's acceptable standard for evaluating the stand and planting value of soybean seeds or any seeds, for that matter. Delouche (8) pointed out the limitations of the germination test in not adequately serving the interests of the farmers, who need more assurances of the stand and crop producing potential of the seed for planting, or those of the seedsman who would like to provide such assurances of seed quality to the user.

He gave three main sources of deficiencies: the overall philosophy of germination testing, the nature of seed deterioration, and germination labeling. In germination testing, the principle of optimization prevails to obtain maximum germination percentages. Germination tests then are conducted on man-made, standardized, sterile media in properly humidified and temperature-controlled chambers for periods of time sufficient for even the last germinable seed to emerge from the embyro and develop into a normal seedling. These ideal conditions allow the seeds to give maximum germination under laboratory conditions; however, conditions in the field are far from ideal, and a seed lot showing a high germination percentage in the laboratory may give low emergence when planted under unfavorable conditions. The physical purity test is another test used for evaluating seed quality in terms of the pure seed, other crop seed, and inert matter content of seeds. In seed testing, a germination test is always accompanied by a purity test.

Seed testing is routinely conducted according to various rules (1, 5, 6, 13, 14). This somewhat new area of activity is vital to determining, maintaining, and predicting seed quality as part of seed quality control programs of developing countries.

This paper summarizes the germination and purity testing of soybean seeds and emerging trends in testing techniques. Some research areas that need investigation have also been mentioned.

LITERATURE REVIEW

The literature on germination and purity testing of seeds is voluminous; however, information about soybeans is scanty, beyond the rules (1, 2, 5, 6, 13, 14) specifying methods of testing germination and purity.

Reports on the effects of substrate moisture in germination are conflicting. In 1969, following five years of investigations covering twelve species, researchers reported that substrate moisture was not critical in determining total germination (23). Belcher (3, 4), studying tree seeds, produced maximum germination using cellophane paper with a moisture content of 23 to 88 percent of its water-holding capacity; however, a water level of 10 percent reduced germination of *Picea* spp. For *Pinus sylvestris*, germination was reduced at the 25 percent moisture level, while for *Pinus palustris* germination was reduced with moisture levels below 37 percent of the water-holding capacity. In 1961, Evans and Stickler (10) studied five cultivars of sorghum (*Sorghum bicolor* (L.) Moench) grains and reported that, under various degrees of moisture stress at temperatures of 15° C and 27° C , increasing moisture stress decreased germination. At lower temperatures it increased the time required for germination.

Since field stand and establishment is a combination of seed of adequate quality

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and field conditions suitable for germination and subsequent growth of seedlings, Hunter and Ericksen (11) showed that seeds of sugar beets *(Beta vulgaris* L.), corn *(Zea mays* L.), soybeans *(Glycine max* (L.) Merr.), and rice *(Oryza sativa* L.) did not germinate above a certain water tension, the minimum germination moisture content being seed-specific. Recent work by Skinner and Schroeder (19) evaluating paper towels and sand for testing germination showed that results from sand were more variable than those from paper towels. This variation may be due to differences in the sand used by the different laboratories, since the paper towels used were provided by the laboratory to the Association of Official Seed Analysts and International Seed Testing Association laboratories testing soybean seeds. The work further showed that the better seed lots gave higher percentages of tolerance among laboratories than did the poor seed lots, when using sand or towels. Observation in the seed testing laboratories in the Philippines confirmed other reports (22) on the use of upright tests to give better and faster results in soybean seed germination tests.

Recent developments point out that there is a need for uniformity in assessing effects of breakage on soybeans. Stanway (20), working on the germination response of soybeans with damaged seedcoats, suggested that lots containing high proportions of seeds with shattered seed coats, cracked seed coats, or transverse breaks in the seed coats could result in poor stands in the field. In large-seeded soybeans with severely shattered seed coats or transverse breaks in the seed coats across the cotyledons, the root shoot axes appeared to be adversely affected.

In 1978, Stanway (21), working on Forrest, a small-seeded soybean cultivar, confirmed her previous findings that the amount of damage to the seed coat is an important seed quality index and should not be ignored. Her experiments had shown that soybean seeds with seed coat breakage or cotyledon breakage gave low germination and would not contribute to field stand. She further emphasized that classifying seed with transversely broken cotyledons into pure seed or inert matter categories should be based on whether the embryonic axis is present in the broken piece. The embryonic axis must be present before it can be considered pure seed.

GERMINATION TESTS

Germination testing of soybeans in the tropics can be problematic. When the rules for seed testing were established, information about methodology was based on temperate conditions; however, when the crop was acclimatized in the tropics, growing conditions varied, and so did the requirements for germination in the laboratory and in the field.

Reasons for Testing Seeds

There are many reasons for testing seeds:

1. To determine the planting value of seeds;
2. To determine disposition of seeds;
3. To determine pricing of seeds;
4. To evaluate research:
5. To label seeds;
6. To determine blending capabilities; and
7. To determine potential quality problems and explore solutions to those problems.

Objective of the Germination Test

The objective of the standard germination test is to determine the percentage of seeds that will grow into normal plants under favorable conditions.

DEFINITION OF GERMINATION. There are many definitions of germination from the various points of view—that of the agronomist, the botanist, and the seed technologist. For uniformity of interpretation, germination is defined as the emergence and development of those essential structures which, for the kind of seed in question, are indicative of the ability to produce a normal plant under favorable conditions (1, 6, 13).

This definition requires understanding and knowledge of the structures of the seed and seedling in order to classify a germinated seedling. In soybeans, a seedling is considered germinated when the following structures are present: a normal root system, a normal hypocotyl, normal cotyledon, and an intact terminal bud (1, 2, 5, 6, 13, 18, 22).

Requirements for Germination

For soybean germination testing, the following requisites are considered: (1) adequate moisture; (2) optimum temperature; (3) aeration; and (4) substrata.

The rules for seed testing (1, 6, 13) indicate that adequate moisture must be provided in relation to the aeration requirement, the kind of substrata used, and the kind of seed. However, application of these recommendations for soybeans or for any crop, for that matter, is very vague. Critical decisions on questions of substrata moisture are left to the hands of the analysts (16).

The rules state that water should be added until the consistency of the soil is such that the ball formed by squeezing it in the palm of the hand is easily broken when pressed between two fingers. After the soil is wet, it should be rubbed through a sieve and placed without packing into the containers for the test.

This recommendation is very arbitrary and would result in variations in moisture content and, ultimately, variations in test results. The temperature requirements for germination for soybeans are 20° to 30° C. Observations in the Central Seed Testing Laboratory, Manila, showed that soybeans germinate equally well under room conditions at constant temperatures ranging from 28° to 30° C , depending on the time of the year. In the tropics, the possibility of using temperatures above 25° C has some merit.

There are many kinds of substrata and methods employed by laboratories for testing soybeans. The alternate methods included in the rules (13) are the between-paper (BP) method and the sand or soil (S) method. For the between-paper method, some laboratories use paper toweling, filter paper, and other paper produced locally in some countries. Soybeans can be germinated in rolled towel tests in upright, slanting, or flat positions.

Seedling Evaluation

The current categories for normal seedlings according to ISTA rules (13) as applicable to soybeans are:

1. Seedlings that show the capacity for continual development into normal plants when grown in good quality soil and under favorable conditions of water supply, temperature, and light;
2. Seedlings that possess all the following essential structures when tested in artificial substrata:
   a. A well-developed root system including a primary root;
   b. A well-developed and intact hypocotyl and/or epicotyl without damage to the conducting tissues, and, in dicot, a normal plumule; and
   c. Two cotyledons.
3. Seedlings with the following slight defects, provided they show vigorous and balanced development of the other essential structures:
   a. Seedlings with superficial damage or decay to the essential structures of the seedlings that is limited in area and does not affect the conducting tissues; and
   b. Seedlings with one cotyledon.
4. Seedlings that are seriously decayed by fungi or bacteria, but only when it is clearly evident that the parent seed is not the source of infection and it can be determined that all the essential structures are present.

At the end of the germination tests, the seeds and seedlings are classified into normal, abnormal, or dead seeds or seedlings and hard seeds.

For the past 40 years, seedling evaluation manuals have been published (2, 24). However, even today, problems of uniformity of evaluating soybean seedlings still exist. With present categories for normal and abnormal seedlings, there are still instances when germination tests result in great variation, especially on marginal seed lots.

Reporting of Germination Tests

For soybeans, the germination percentage is the average of at least two replicates of 100 seeds each within tolerance; it is reported in a whole number.

Purity Tests

The objective of purity analysis as contained in the rules (1, 5, 6, 13) is (1) to determine the composition by weight of the sample being tested and, by inference, the composition of the seed lot; and (2) to identify the various species of seed and inert particles constituting the sample.

In the purity test, the sample is separated into crop seed, inert matter, and other crop seed, and each component is reported as a percentage.

For soybeans, pure seed refers to and includes all cultivars and species under consideration, as stated by the sender or found by the laboratory test. In addition to mature, undamaged seed, pure seed shall include:

1. Undersized, shriveled, immature, and germinated seeds;
2. Pieces of seed resulting from breakage that are more than one-half their original size, but not seed with the entire coat removed, which shall be regarded as inert matter; and
3. Diseased seeds, except those altered by fungi to form fungal sclerotia or smut balls or nematode galls, which shall be regarded as inert matter.

RESEARCH NEEDS

Rules for seed testing have been in existence and used for the past 40 years with slight changes or no changes at all (17, 24). In order to keep up with the changing need in agricultural production for better quality seed, there is a need to review and assess seed quality in terms of the seed input required to maximize crop yields. In terms of a pure seed definition for soybeans, there is perhaps a need to adopt a more meaningful definition and to put purity testing in a more acceptable position as an index of seed quality.

In terms of germination tests, much effort has been directed toward developing, describing, and agreeing upon methods that are reproducible within tolerance limits between laboratories and between countries. There are direct methods that take time, space, expense, and energy, since they involve the germination of seeds under optimal conditions. Current trends in germination testing are shifting from direct methods to tests that can be conducted rapidly and cheaply and give some indication of field emergence in unfavorable field conditions. These methods must be reproducible and easily standardized (15).

Many of the rules are not relevant to the needs of the changing time. Grabe (12) pointed out the outmoded concepts and inadequacies of the rules. General trends in germination testing from 1931 to 1968 were discussed at length by Wellington (24).

Research work on seed testing had been conducted mostly in the developed world, and emphasis had been on economic crops important to those various countries. The importance of the soybean seed industry was not recognized until the early 1950s (8). In the tropics, where soybeans are emerging as an important crop, seed quality problems had been put aside for a while, behind varietal improvement and production. The technical committee on germination of the International Seed Testing Association established a subcommittee on germination testing of tropical and subtropical species, and soybeans were one of the crops considered. Limited resources dictate that the work of the committee be confined to referee testing and a survey of the methods employed by ISTA stations testing soybeans.

In this context, the following are identified as researchable areas in germination and purity testing in the tropics:

1. Assessment and development of rapid, inexpensive, energy-conserving, field performance indicative methods for testing germination of soybeans in the tropics;
2. Studies on seedling evaluation;
3. Studies on concrete prescriptions for germination methods; and
4. Application of the pure seed definition of purity analysis.

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DISCUSSION

M.D. Tedia: Some given varieties under drought stress tend to produce a lot of hard seeds, and these hard seeds are counted as normal seedlings. If the hard seeds do not germinate in the field, this will be a disastrous condition from a practical point of view. Will you consider treating the seed with fungicide before you keep it in capsule for seed germination?

Erlinda Pili-Sevilla: Because our experience, and some literature, shows that hard seeds in soybeans do contribute to field stand, they are reported as part of the germination percentage. Seed treatment is not recommended in seed testing, but in certain cases we do recommend treatment with tests showing severe infection.

A. Sajjanongse: Seeds from different locations, i.e., the U.S.A. and the Philippines, are put under different temperatures according to the temperatures of their environments of origin for testing and seed emergence rate. Would it not be more appropriate to test them under the same temperature, regardless of their origins, since all of them are for planting in the same location?

Erlinda Pili-Sevilla: Our practice is to put them in the two conditions and issue the results of both tests.

M.E.R. Pinto: According to your experience, what is the period of germination spread in samples from the Philippines?

Erlinda Pili-Sevilla: Eight days. Germination of most lots we test fall within the prescribed period of eight days at room temperature of 28° to 33° C. In deeply dormant seed, the spread will be greater, but we do not have deeply-seated varieties in the Philippines.

J.A.G. Joshi: How many soybean seed samples are tested in your lab in one year? What is the percentage of samples that come from soybean farmers?

Erlinda Pili-Sevilla: The number of samples we test is minimal--less than 50 samples a year. Only about 1 percent comes from farmers.

Flavia Kabeere: Soybean seeds tested in filter papers have to be germinated in incubators or places that do not encourage evaporation. This system means that application light facilities are not appropriate. Seeds germinated in incubators have been found to have slow germination with cotyledons that do not open early enough to allow easy evaluation of the shoots. Delaying germination (beyond five days, according to ISTA, 1966) leads to decay of hypocotyls. Sand has been found to be a better substitute for filter papers as seedings do not have so great a need to be protected from evaporation. Has any experience of this nature been observed?

Erlinda Pili-Sevilla: Generally not. The roll-towel method does not give similar problems when seeds are taken at 28° to 30° C. Therefore, the problem may be attributed to temperatures used (23° to 25° C), which encourage slow growth.

Seed Testing: Detection of Pathogens

J.B. SINCLAIR

Every population of soybean seeds has the potential of carrying a variety of microorganisms, including fungi and bacteria and viruses (8). These may be on the outside of the seed coat (externally borne), established in the tissues of the seed coat (internally borne), or in the tissues of the embryo (internally borne) (6, 8, 9). Many of these are pathogens and can cause disease in the germinating seeds, in seedlings, and in plants, or affect the embryo before the germination process begins. The nature of seedborne pathogens of soybean has been summarized (7). Since all seeds are attacked by pathogens, much of the expense involved in seed production is related to controlling them through manipulation of the environment by use of chemicals as well as by handling and packaging methods.

There are a number of methods for the testing and identification of microorganisms and viruses associated with soybean seeds. Some of the simpler ones that can be used in most laboratories will be discussed.

SYMPTOMOLOGY

Some pathogens associated with soybean seeds produce characteristic symptoms on the seeds (6). The symptoms produced on seeds by some of the more important fungal, bacterial, and viral pathogens are summarized.

Fungi

Cercospora kikuchii (T. Matsu and Tomoyasu) Gardner (causal organism of purple seed stain). Seed discoloration varies from pink or pale purple to dark purple, the latter being the most common. The discolored areas may occur anywhere on the seed coat and vary in size from specks to large irregular blotches, or they may cover the entire surface of the seed coat. Rarely does the discoloration appear on the cotyledons of the embryo.

Cercospora sojina Hara. (the causal organism of frogeye leaf spot). Infected seeds have conspicuous gray to brown to charcoal discolored areas, ranging in size from minute to large zonate spots, usually with some cracking and flaking of the seed coat. There is often a brownish cast around the hilum, where most seed infection seems to occur (12).

Colletotrichum dematium (Pers. ex Fr.) Grove var. *truncata* (Schw.) Arx. (the causal organism of anthracnose). Seed infection may show no symptoms or it may be expressed as small, irregular gray areas with minute specks. Heavily infected seeds are wrinkled. Symptomatic areas occur anywhere on the seed coat. The fungus becomes established in the seed coat and can invade the cotyledons of the embryo.

Macrophomina phaseolina (Tassi) Goid. (the causal organism of charcoal rot). Symptoms are similar to those of *C. dematium* var. *truncata*. The specks are sclerotia.

Phomopsis spp., *Phomopsis sojae* Leh., *Diaporthe phaseolorum* (Cke. and Ell.) *sojae* Wehm., *D. phaseolorum* (Cke. and Ell.) Sacc. var. *caulivora* Athow and Caldwell (the causal organism of Phomopsis seed decay, pod and stem blight, stem canker). Any one or all of these fungi may occur in infected seeds (5). Seeds may be symptomless carriers. Heavily infected seeds are badly cracked and shriveled, and often they are partially or completely covered with whitish mycelium. Infected seeds tend to be elongated and smaller than noninfected seeds. The fungus first becomes established in the seed coat and can colonize the cotyledons of the embryo.

Peronospora manshurica (Naoum.) Syd. ex Gaum. (the causal organism of downy mildew). Seeds may be partially or completely encrusted with a whitish mass of mycelium and oospores. Oospore-encrusted seeds appear dull white and have cracks in the seed coat. Seeds may be smaller and/or lighter in weight than normal

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seeds. The fungus may not colonize the tissues of the seed coat or embryo but may remain on the surface of the seed.

Bacteria

Bacillus subtilis (Ehrenberg) Cohn (the causal organism of Bacillus seed decay). The bacterium is omnipresent and is probably associated with soybean seed lots produced anywhere in the world (4, 9). Symptoms are produced under very moist, warm (25° C or above) conditions and consist of a soft rot or decay of the seed. Severely decayed seeds may be covered with a slimy, rough or smooth-type bacterial growth, which is whitish to greyish in color. The bacterium is grampositive and a spore producer.

Pseudomonas syringae pv. *glycinea* (Coerper) Young, Dye and Wilke (the causal organism of bacterial blight). Stored seeds show a variety of symptoms including shriveling, sunken or raised lesions, or slight discoloration, or they may be symptomless. Under high moisture conditions a slimy growth may appear on the surface of infected seeds. The bacterium is germ-negative.

Virus

Soybean mosaic virus (the causal agent of soybean mosaic). Soybean seeds from soybean mosaic virus (SMV)-infected plants may or may not show symptoms. Viable seeds from diseased plants may be smaller than those from noninfected plants. Yellow-seeded cultivars infected with SMV may produce seeds that are mottled brown or black, depending upon the hilum color. The mottle usually appears as "bleeding" of the hilum pigment over the seed coat.

The soybean seed can be a microcosm of microorganisms. A single seed can be colonized by more than one fungus and/or a bacterium and show symptoms caused by more than one invader. Soybean seeds can be symptomless carriers of fungi and bacteria. Thus, a single symptom on a seed does not necessarily mean that there is only one microorganism present. A diagnosis for the microorganisms present in any one seed lot should not be based on symptoms alone. For example, seeds showing symptoms of soybean mosaic may or may not have the virus in them, and seeds without symptoms from an SMV-infected plant may carry the virus and not show symptoms. Symptoms of soybean mosaic on seeds indicate only that the seeds came from an SMV-infected plant. Soybean seeds must be assayed to determine the nature of the seedborne organisms involved.

ASSAYING SOYBEAN SEEDS

Soybean seeds are frequently contaminated on the surface with a variety of microorganisms, such as species of *Alternaria, Aspergillus, Penicillium,* and *Rhizopus*. These fungi grow rapidly under warm, moist conditions, such as those used in most assay methods, and soon cover other more slowly growing fungi and bacteria. Therefore, it is necessary to surface-sterilize soybean seeds being assayed for the presence of internally seedborne fungi. Surface sterilization can affect germination (12), and sterilants can be selective for certain fungi (1).

Sterile Water Assay

Sterile water can be used in two ways. Washing a known quantity of seeds in a known quantity of sterile water and planting the washate onto an agar medium will help in studying the microorganisms found on the outside of the seed. Seeds can be placed in culture plates (or other covered glass or clear plastic containers) with just enough sterile water to cover the bottom. The fungal growth on the seeds should be observed daily and examined under a dissecting microscope (12).

Filter Paper Assay

Filter paper moistened with sterile water and placed in a sterile, covered glass or clear plastic container can be used to assay for microorganisms associated with soybean seeds (10). Seeds should be examined daily, since some fungi grow and produce fruiting structures before others. This technique has been used successfully to assay for *Cercospora kikuchii, C. sojina, C. dematium* var. *truncata* and the *Phomopsis* spp. complex (5, 11, 12).

Cellulose Pad (Kimpac) Assay

Cellulose pads are used frequently when assaying large volumes of seeds (5). In seed-testing laboratories, soybean seeds assayed on cellulose pads often are not surface-sterilized. Only the predominant, fast growing microorganisms are usually encountered when using this technique.

Agar Plate Assay

Seeds should always be surface-disinfected when the agar plate method is used, unless a selective agar medium is used. Water agar, potato-dextrose agar, and decoction agars made from soybean plant parts, such as seeds, pods, stems, and leaves, are commonly used (11). The growth of *C. kikuchii* is favored by carrot-leaf-decoction agar (11), and that of *C. sojina* by V-8 juice agar (12). Two selective media have been used for isolating *Macrophomina phaseolina* (3).

Rolled Paper Towel

Moist paper towels with seeds placed equidistant from one another can be used for assay. Although many fungi do grow and fruit under these conditions, others do not, and the seed or seedling tissues must be assayed further to determine the pathogens involved in seed injury or kill.

Indicator Plants

Occasionally a worker will isolate a nonsporulating fungus. Inoculating germinating soybean seeds, seedlings, or young plants with the unknown may induce sporulation.

The identification of plant viruses can be accomplished with a group of selected indicator plants or, in the case of SMV, infected seeds will give rise to seedlings with characteristic symptoms under the proper conditions (8).

Seedborne microorganisms with optimum conditions for growth and reproduction that are above or below standard incubation conditions may not be detected by the various assay methods described.

INCUBATION CONDITIONS

Generally, incubation at a relative humidity approaching 100 percent and a temperature range of 23° to 28° C is favorable for the growth of most fungi associated with soybean seeds (7). Many fungi will grow and fruit under ordinary laboratory conditions, but others, like the *Cercospora* spp., require special lighting (alternating light and dark) or ultraviolet light (11, 12). Seeds from the same seed lot should be incubated under a range of temperatures, light sources, etc., to determine fully all the fungi and/or bacteria associated with the seeds. If studies are to be made on isolates of a particular fungus or a group of fungi, the environmental conditions required for growth and reproduction of that fungus must be determined.

IDENTIFICATION OF PATHOGENS

Caution should be taken in the identification of microorganisms associated with soybean seeds. A large number of fungi have been reported associated with soybean seeds (1, 2, 6, 7, 10). Identification based on culture characteristics should include examination with a hand lens, under a dissecting microscope or glass-slide preparation, or under a compound microscope. For example, *C. kikuchii* and *Chaetomium cupreum* have similar culture characteristics in vitro, so the latter may be mistaken for the former if a careful examination is not done (10).

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Factors Affecting the Sowing of Soybeans: Cropping Methods

ARWOOTH NA LAMPANG

Due to their short growth duration (100 ± 10 days), their adaptability to short spells of moisture deficiency and excess, their high yield potential, and their soil-improving capacity, soybeans have been a preferred component in traditional cropping systems widely practiced by Thai farmers. The first program to promote the growing of soybeans in Thailand, initiated about 1930, sought the acceptance of soybeans as a sequence crop to follow the main rice crop in the north. The idea was well received wherever irrigation facilities were available during the dry season. The second such program was in the rainfed uplands of the upper central plain of the Kingdom, where soybeans were promoted as an early-season crop to be planted in May and relayed with cotton to utilize precipitation in the later part of the rainy season. The most recent effort to grow soybeans after a crop of corn, in the lower central plain, has not yet been as successful as the first two cropping patterns because of the unreliable rainfall distribution in the area. Farmers are often unable to plant corn early in the season because of a delayed monsoon, which, in turn, delays the sowing of soybeans and results in a low yield due to inadequate moisture. Under these conditions, mungbeans, which have a shorter growth duration, compete with soybeans and occupy a larger area as a late rainy-season crop.

LITERATURE REVIEW

One of the main objectives of the soybean breeding program has been to evolve cultivars suitable for existing cropping patterns (3). The selection criteria are high yield, short and erect stature, short growth duration, and photoperiod insensitivity coupled with desirable agronomic characteristics, such as resistance to major pests and seed quality. These characteristics are sought for intercropping and relay cropping systems in order to minimize interspecific competition, particularly shading.

In the more popular irrigated rice-soybean system, seeds are usually dibbled into fresh or burnt rice stubble (4). In this sequence there is no problem either in establishing plant stands or in insuring normal growth. Yield level and seed quality are both excellent under proper management and pest control. However, early planting, immediately after the rice harvest (or before January), will produce a better crop than late sowing, mainly due to the shortage of irrigation water toward the end of the growing period.

In a rainfed soybean-cotton relay, establishment of the soybean stand is more critical. In order to provide sufficient time for cotton growth, soybeans are sown with the first heavy rains from late April to early May. Plant stand and crop growth depend on subsequent rains; if the rains fail, soybeans may have to be resown. To insure a reasonable plant stand, farmers use a heavy seed rate, up to 20 plants per hill. In a normal or above normal season this number results in excessive plant density initially and lodging at later stages of growth. Cotton is interplanted about 60 days later when soybeans are in the early-pod stage. Generally, soybean yields are not as high as in the rice-soybean system due to erratic rainfall, weeds, and pests that are difficult to control in the rainy season. Furthermore, grain quality is somewhat poor since harvesting of soybeans occurs in the peak of the rainy season (August to September), when plants can be dried only under shade before they are threshed in October and November. About two-thirds of the commercial soybean grain is produced from the rainy-season crop.

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In the more recent corn-soybean pattern, corn is planted at the beginning of the monsoon and harvested in July or August. Soybeans are sown immediately after the corn harvest. A good yield of soybeans is expected if the rains extend up to the middle of October, that is, up to about a 75-day soybean-growing period. In some years a late onset of the monsoon delays soybean sowing, and this delay in turn results in a decreased yield to a variable extent. Similarly, the early cessation of rain also reduces soybean yields. Typhoons, which usually appear during September and October, also affect the soybean crop. Incessant rains cause severe crop lodging and also encourage the outbreak of major diseases, such as rust *(Phakopsora pachyrhizi)*, anthracnose *(Colletotrichum dematium* var. *truncata)*, pod and stem blight (*Phomopsis* spp.), and several bacterial diseases. On the other hand, occasional storms contribute to soil moisture and extend the growing season. More often the yield is low, but seed is of good quality since the soybean harvest occurs in the dry season.

Recently, demand has been heavy for mungbeans and black gram, and these crops have been bringing higher prices on the foreign market. Most of the land is now being sown to mungbeans and black gram after corn. These two crops are competitive with soybeans for time, land, and labor at present. Since mungbeans and black gram are more dependable and more profitable, soybeans have become less popular.

CURRENT RESEARCH AND DEVELOPMENT

In addition to a rice-soybean, soybean-cotton, and, to a lesser extent, a corn-soybean pattern, several experimental crop patterns have been studied for possible future use. Experiments are in progress on soybeans inter- or relay-cropped with corn, cassava, castor beans, kenaf, cotton, sugarcane, and sesame. The main purpose of the experiments is to find appropriate techniques for improving cropping intensity and crop production. The focus is on optimum population density and stand establishment, row width, spacing, and time of planting of soybeans in relation to the base crops. Criteria for assessment of the systems are (1) Land Equivalent Ratio (LER) as suggested by IRRI; (2) profitability measured in terms of gross, net, and marginal returns; and (3) risk measured by stability of yield and frequency of "disaster returns." An LER greater than 1.4 is considered generally acceptable for further refinement and modification to determine costs and returns.

The more important features of the above studies are highlighted in the following discussion.

RELAY- AND INTERCROPPING

Optimum Plant Density

Crop yields will be high only if plant population density is optimum and the distribution of plants is fairly uniform. Optimum density and uniform distribution require high quality seed. Proper land preparation, soil moisture, and depth of planting determine the velocity of seedling emergence and stand. These requirements apply irrespective of sole, sequence, relay-, or intercropping patterns of cropping.

In general, spacing for a sole crop of soybeans is recommended at 50 x 20 cm, or 200,000 plants per ha (2) (Table 1).

The optimum plant density in intercrop systems is generally higher than for sole crops since the plants do not grow and branch normally when subjected to interspecific competition (6, 7). Data from cassava-soybean intercrop planting bring out the need for a higher plant density with soybeans (2).

	Hill spacing 10 cm (1 seed/hill)	Hill spacing 20 cm (2 seeds/hill)
Yield (gm/m^2)	70.3	55.2
Least Significant Difference (LSD)	4.65	

Row Widths

A series of studies has been conducted recently with soybeans (S) as an intercrop and caster beans, cotton, cassava, kenaf, and others as base crops (C).

As a rule, the recommended row width of the base crop is adopted. Between the rows of the base crop, rows of soybeans are accommodated. For example, cassava row width is set at 100 cm, and two rows of soybeans are interplanted (Fig. 1). In this arrangement the equivalent row spacing of soybeans is 50 cm. Mutual competition is generally a serious problem in intercropping.

Preliminary studies indicate that intraspecific competition is generally less critical than interspecific competition. Hence, it is desirable to have the two rows of soybeans as close as possible to one another and as far away as possible from the adjacent cassava row. Systematic (continuous variable) designs are particularly valuable in determining the range of separation distance (X) over which the yield of soybeans remains unaffected (Fig. 1).

Shelke (1977) has shown that X can be as small as 10 cm for sorghum-soybeans. Our results from the cassava-soybean intercrop in 1979 (1, 2) confirm that X need not be greater than 12 cm. It follows that rows of soybeans may be paired 10 cm apart and 45 cm from the nearest cassava row.

Row Number

The effects of number of soybean rows on yield of soybeans and cassava have been studied (5). The first effect is increased plant density, which is reflected in a greater yield of soybeans with each added row (Table 2). The second effect is increasing competition with cassava, which results in progressive yield reduction of cassava. Data not presented in this paper indicate that the system is optimized only when two rows of soybeans are planted with hill spacing adjusted to maintain an optimum population, that is, to 10 cm (1).

It is preferable to harvest a crop in dry, clear weather, and this advantage can usually be assured by adjusting planting time. To cite an example, cotton has to be picked in the dry season, after the rains cease, in order to obtain high quality fiber. Therefore, planting of cotton is delayed until June or July. Intensive studies on soybean-cotton relay cropping have been undertaken since the large area under this system is of great economic importance.

The analysis of cotton relayed in soybeans illustrates several noteworthy issues (2). Soybeans are planted with the first soaking rains from late April to early May, with spacing of 50 x 20 cm (2). Cotton is interplanted 45 to 60 days later, in June or July. The soybean yield is excellent (about 1.5 t/ha) comparable to soybeans as a sole crop, but the cotton yield is very low, about 200 kg of seed cotton per ha. The LER of this pattern is 1.2 or less Since the unit price of cotton is nearly double that of soybeans, and since cotton needs costly protective measures against insect pests, income from this pattern is less than from sole crops. Refinement has been made by pairing soybean rows 10 cm apart and interplanting cotton 60 days later. Data are not yet available from the 1980 season. However, it is clear from field observations that shading of soybeans on cotton is not much reduced. Cotton is stunted, with few branches and fewer bolls.

This finding leads to the idea of widening cotton rows to 15 cm to keep optimum cotton population density (20,000 plants/ha) with single or paired rows of soybeans. The equivalent row width for soybeans will increase to 75 cm, but plant density will be maintained at the 200,000 plants/ha optimum, and cotton planting will be done 15, 30, and 60 days after soybean sowing. This refinement will be tested in the 1981 rainy season. One advantage of the soybean-cotton pattern is that the income from soybeans will finance protection of the relayed cotton crop against insect pests.

Data on relay planting of cassava (1, 5) between soybean rows indicate that it is not only operationally more convenient but also more remunerative to plant cassava and soybeans simultaneously (Table 3).

CROP STAND: SKIPS AND COMPENSATION

Studies on soybean spacing and density have shown that yield will be maximum if plant populations are kept at an optimum of 200,000 plants/ha, and if row widths and hill spacing are not of critical importance. Significant reduction in yield occurs when plant population density is reduced below 80 percent of optimum density.

It has also been observed that shading of fast-growing base crops such as corn, sesame, and kenaf has direct and indirect effects on soybean population and yield. Adjustment of soybean planting time relative to the base crop appears to be more promising than refining crop geometry alone. At present, information on this aspect is sketchy.

EFFECT ON SEED QUALITY

In tropical monsoon countries, production of quality seed depends largely on the weather at harvest time. In sequence cropping like rice-soybeans, seed quality is best if soybeans are planted right after the rice harvest. The harvesting of soybeans can then be completed before the premonsoon showers from late March to early April. In the corn-soybean pattern, soybeans are usually harvested after the rains

Table 1. Effect of Row Spacing and Plant Population on Soybean Yield

	50-cm row			75-cm row		
Plant density (thousands/ha)	200	400	600	135	270	405
Yield (t/ha)	1.86	1.67	1.63	1.66	1.85	1.61

Table 2. Effect of Soybean Row Number on Yield: Mean of 11 Location-Years

	Yield (t/ha)		Relative percentage		
Patterns[a]	S	C	S	C	LER
0 + 0	...	28.86	...	1	1
1 + 0	0.66	23.57	0.44	0.82	1.26
0 + 2	0.79	22.82	0.53	0.79	1.32
1 + 2	1.07	20.96	0.72	0.73	1.45

Note: Sole soybeans are not included but are assumed to yield 1.5 t/ha.
[a]Respectively sole cassava, one soybean row within rows of cassava, two soybean rows between rows of cassava, and a combination of patterns 2 and 3.

Table 3. Relay Planting of Cassava in Soybeans

Days[a]	0	20	40
Cassava (t/ha)	24	12.56	3.19
Soybean (t/ha)	0.612	0.837	0.65

[a]Days after planting soybeans.

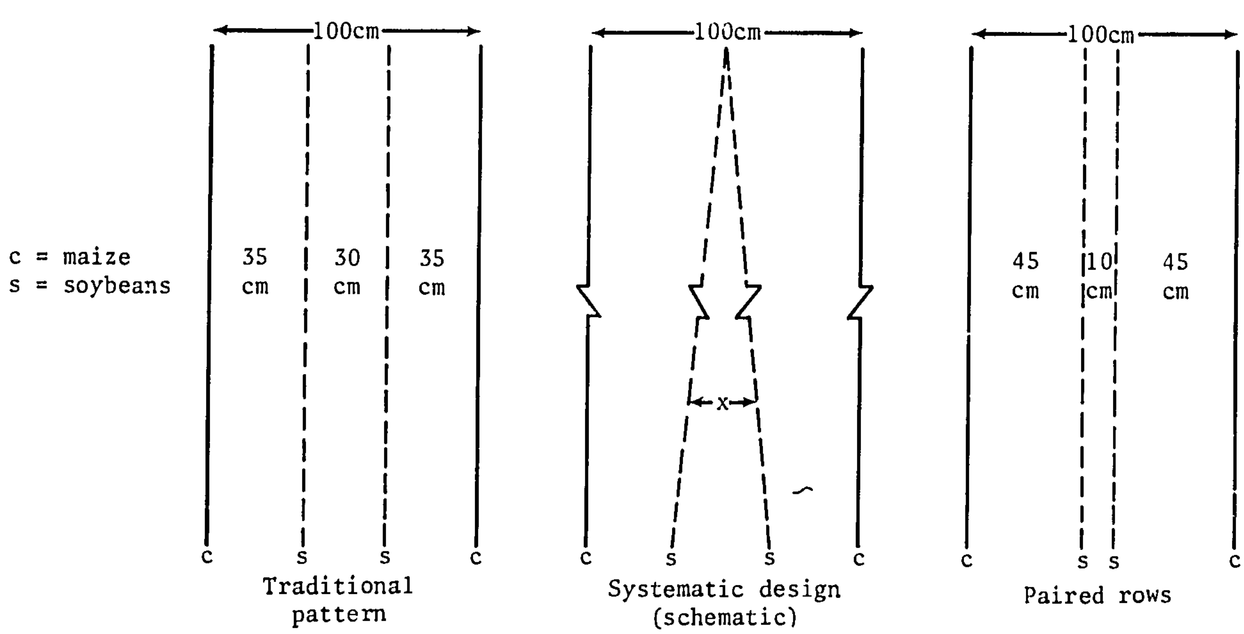

Fig. 1. Suggested arrangements of rows to study competition between maize and soybeans.

cease. Only in planting in the early monsoon season does seed quality tend to be poor because it rains during the harvest and there are no rapid-drying facilities at the farm level. Agencies involved in seed production must be equipped with facilities necessary for producing good quality seed. Experience in Thailand indicates that cropping systems have more effect on plant stand and establishment, and, in turn, on yield than on seed quality.

CONSTRAINTS ON EFFICIENT PRODUCTION

Attempts to improve the efficiency of the traditional cropping systems raise several problems, especially with relay- and intercropping. First, soybean cultivars suitable for intercropping with a given base crop are not yet available. Each base crop possesses different growth habits, so it is very difficult, if not impossible, to evolve a soybean cultivar with specific adaptation to a given base crop. A breeding program for that purpose has been initiated, but progress is slow due to a paucity of funds and personnel.

The second constraint is the uncertainty of weather, such as the onset and cessation of the monsoon and the distribution of rain. Since most of the base crops are grown in rainfed uplands, weather dictates the success of crop production. Alternative crop patterns should be available that are suitable not only for the various agro-ecological zones but also for meeting the weather contingencies within each zone. For example, in areas where soybean-cotton relay cropping is the rule, mungbeans with their shorter growth duration should replace soybeans if the onset of rains is later than May.

The LER index for efficiency of crop productivity has little value in determining the cost-benefit ratio. Farmers always prefer patterns that give them a higher cash return. Also, the area under one well established base crop will gradually change to another less adapted base crop if the latter commands a higher price in the market, as cassava has replaced kenaf, for example, in northeastern Thailand.

There are other constraints on efficient production, such as soil condition, fertility, pest management, the availability of planting seeds, and socio-economic factors. A systematic and long-term approach to both station experiments and on-farm testing will help substantially to elucidate these problems and suggest alternative solutions.

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DISCUSSION

C.L. Wang: Will you please give an example of the specific types of cultivars that would be appropriate for this specific cropping method?

Arwooth Na Lampang: The leading crop should be early enough to allow the second crop to be grown as soon as possible. For soybeans, we are looking for an early variety that can be harvested within 85 days. In the case of intercropping, the best variety should behave like rice beans that can be grown in the corn, as I have already indicated in my presentation.

Seed Dressings and Rhizobium Inoculum

VIJENDRA KUMAR AGARWAL AND J.B. SINCLAIR

Soybeans are one of the most important crops because of their high nutritive value and wide use in different industries. Proper plant stand and good nodulation are the two most important factors in the successful cultivation of soybeans. Soybeans seeds often are treated with fungicides to protect them from seed- and soilborne microflora to assure emergence and plant stand while *Rhizobium* inoculum (*Rhizobium japonicum*) is applied to ensure effective nodulation. Great concern has been shown about the compatibility of a combination of fungicides and *Rhizobium* inoculum. The seed-dressing chemicals have been shown to interfere with *Rhizobium* inoculum. Attempts in different countries are being explored to develop a technology for the treatment of soybean seed with a combination of fungicide and *Rhizobium* inoculum without an adverse effect on nodulation.

LITERATURE REVIEW

The usefulness of treatment of soybean seeds with chemical and *Rhizobium* inoculum has been very well established to ensure better plant stand and good nodulation. The literature on the compatibility of a combination of seed-dressing fungicides and *Rhizobium* inoculum is often controversial and a general apprehension has been raised in most of the soybean-growing countries about the beneficial effect of *Rhizobium* inoculum in combination with fungicides. Attempts are in progress to evolve a combination of seed-dressing fungicide and *Rhizobium* inoculum that could give better plant stand as well as good nodulation. The literature pertinent to the various aspects of seed-dressing chemicals and *Rhizobium* inoculum is discussed in the following paragraphs.

Effect of Seed Treatment with Various Chemicals

Fungicides belonging to all major groups, such as antibiotics, benzimidazoles, copper, heterocyclin nitrogenous, mercury, oxathiins, PCNB, quinone, and sulphur, have been tried to determine the effect of seed treatment on *Rhizobium* inoculum. The effects of different seed treatment chemicals on nodulation are presented in Table 1. Most workers have shown that copper fungicides, oxycarboxin (Plantvax), and PCNB (Brassicol) adversely effect nodulation, while aureofungin (a heptaine antibiotic, N-methyl para-amio acetophenone and mycosamine), benzimidazoles (thiabendazole, carbendazim, benomyl), and zineb (Dithane M-45), have no adverse effect. Reports on the efficacy of seed treatment with captan (Orthocide), carboxin (Vitavax), chloranil (Phygon), dichlone (Spergon), mercurials, and thiram are contradictory. The damage due to treatment could be reduced by following certain precautions.

The major precautions against damage to nodulation include: (1) inoculation with an inoculum in a peat moss base medium immediately prior to planting, preferably by wet method with sucrose in the inoculating fluid; (2) maintaining high soil moisture; and (3) using increased doses of inoculum to offset injury to the inoculum caused by the dressing fungicides. Increasing the amount of *Rhizobium* inoculum may not be useful with all the fungicides. In the case of captan and zineb, five times increased levels of *Rhizobium* inoculum did not increase nodulation. However, in the case of carboxin, a slight increase in nodulation was observed with an increase in inoculum level (Dobereiner, personal communication).

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Table 1. Effect of Various Seed Treatment Chemicals on Nodulation

Decrease	No adverse effect	Increase
	Aureofungi (20)	
	Benomyl (12)	Benomyl (8)
Captan (7)	Captan (9, 10, 12)	
	Carbendazim (4, 9)	
Carboxin (8)	Carboxin (7, 16)	
Chloranil (5)	Chloranil (13)	
Dichlone (5)		Dichlone (16)
Copper fungicides (12)		
1 percent Hg as ethyl mercury chloride and phenyl mercury acetate (20)	2.5 percent Hg as methoxyethyl mercury chloride (20)	
		Molybdenum (16)
Oxycarboxin (8)		
Pentachloronitrobenzene (7)		
	Thiabendazole (14)	
Thiram (19, 20)	Thiram (2,7,9,12,15)	
Thiram + insecticide (lindane and/or chlorophyrifos) (19)		
	Zineb (16, 20)	

Note: References in parentheses are to literature cited.

Survival of Rhizobia on Chemically Treated Seed

In general, treated seed should be sown as soon as possible after inoculation because *Rhizobia* die rapidly on seed following inoculation. In an experiment on the survival of *Rhizobia* on chemically treated seed, Curley and Burton (7) found that, on seeds having no treatment, only 40 percent of the *Rhizobia* applied survived for as long as one hour. Captan and carboxin reduced viable *Rhizobia* by less than 20 percent in one hour, whereas PCNB killed 78 percent of the *Rhizobia* during this period. Thiram had no adverse effect on *Rhizobium* survival. Carboxin was found compatible when seeds were planted within four hours of inoculation but not when seeds were held for 24 hours.

Relationship of Laboratory Evaluation of Chemicals and Field Performance

Chemicals found compatible with *Rhizobium* inoculum under plate count tests may not yield parallel results under field conditions. Curley and Burton (7) found that captan, carboxin, and thiram were compatible in plate count tests, but, in field studies on nodule counts at two weeks, only thiram was found to be compatible.

Effect of Seed Treatment on Nodule Number and Weight

The adverse effect of chemicals may be in the form of reduction in total number of nodules and/or size (weight) of nodules. At times, even though the number of nodules may not be sufficiently affected, there may be a drastic reduction in nodule weight. Dobereiner (personal communication) found that the reduction in nodule weight was more pronounced than the reduction in nodule number with seed treated with carboxin and zineb.

Other Factors Affecting Nodulation

The application of *Rhizobium* inoculum to seeds does not ensure nodulation and, likewise, the presence of nodules does not always mean a high level of nitrogen fixation. A number of factors, such as soil pH, soil moisture, soil texture, *Rhizobium* strain, method and time of inoculation, have been shown to affect nodulation (6). Variations in methodology and above experimental variables might probably be playing a vital role in the conflicting reports on the efficacy of compatibility of fungicide-*Rhizobium* inoculum combinations.

CURRENT RESEARCH AND DEVELOPMENTS

Studies in different countries are in progress as to how to eliminate the damage to *Rhizobium* inoculum due to seed-dressing chemicals. It may be through the use of a safe fungicide, the incorporation of fungicide into seed through a solvent carrier so that the *Rhizobium* inoculum does not get into direct contact with fungicide or a fungicide-resistant *Rhizobium* strain, or the application of granular *Rhizobium* inoculum during planting operations. These are the major areas of current research on soybean seed and other legume crops.

Use of Fungicide-Resistant Mutant Strains of *Rhizobium*

It has been found that tolerances of strains differ with regard to their compatibility with fungicides. In beans, cowpea, lucerne, and peanuts, strains have been identified that can tolerate fungicides. Combination of a fungicide with such a *Rhizobium* strain may give even higher nodulation as compared with the control. Odeyemi (17) reported that the mutant strains of *Rhizobium meliloti* or *R. phaseoli* in the presence of thiram on lucerne and chloranil on beans, respectively, and the cowpea *Rhizobium* strain in the presence of dichlone on cowpeas produced 100 percent more nodulation than wild strains. LX717 captan, LX717 carboxin, LX718 thiram, and LX718 PCNB resulted in higher nodulation than the control (2). Backman (2) pointed out that the possible reason for higher nodulation could be that the fungicide causes more *Rhizobium* inoculant to stick to the seed coat. Likewise, there is active research on the possibilities of inoculating bean seeds with a fungicide-resistant strain of *Rhizobium*. Such possibilities are also being considered for soybeans (1).

Use of Fungicides Against Poor Nitrogen Fixers

There is a negative effect when poor nitrogen-fixing or nonnitrogen-fixing organisms compete with effective nitrogen fixers. Studies are in progress to explore the possibilities of using fungicides that kill such competitive, poor nitrogen-fixing organisms in the soil. Thus, fungicides may be useful in increasing the quantity of nitrogen fixed (1).

Use of Granular *Rhizobium* Inoculum

Recently the use of granular inoculants has been suggested to prevent fungicide damage to *Rhizobium* inoculum. The inoculum does not come in direct contact with the fungicide. The granular applicators are used to drop the inoculant near the seed during the planting operation. This has been found workable in the case of peanuts. Encouraging results also have been obtained for soybeans (2). The major drawbacks with this method are that inoculum is expensive and the planter must be fitted with a granular applicator.

Incorporating Fungicide into Seeds Through Solvent Carrier

The methods normally used for seed treatment are ways of mixing fungicides with seeds either manually or mechanically. The fungicide remains on the surface of the seed, or a mixture of fungicide and *Rhizobium* is applied to the seed. The direct contact of the fungicide with the *Rhizobium* may be lethal. Recently Sinclair (18) reviewed works on using anhydrous dichloromethane (DCM) as a carrier to introduce chemicals into seeds. It was found that DCM facilitated the movement of methylbenzimidazole carbamate (MBC) and thiabendazole into dormant seeds. The solvent carried the antimicrobial material into the seed coat and evaporated when allowed to air dry, thus leaving the fungicides in the seed coat. Thus, the chances of interference of *Rhizobium* inoculum with fungicide that is inside the seed may be less than with dry or slurry seed methods being followed. Such seed treatment techniques may promise to reduce the damage to the *Rhizobium* inoculum.

Evaluating the Effect of Seed Treatment

Backman and Carter (3) developed a bead method for determining the effect of seed treatment chemicals on the *Rhizobium* inoculum by using glass beads (5 mm) instead of seed. They found that *Rhizobium* survival was lower on seeds than on the glass beads, which proved to be better because the factors such as antagonistic microflora on or in seed or the effects of seed respiration on the *Rhizobium* inoculum were eliminated. The bead method may prove useful for quick screening of large numbers of combinations of chemicals and/or *Rhizobium* strains under laboratory conditions with more sensitivity. Jain and Rewari (11) found that none of 25 bacteria, five fungi or four actiomycetes tested showed any antagonism to *Rhizobium* sp.

CONSTRAINTS ON EFFICIENT PRODUCTION

The complex nature of compatibility of seed-dressing fungicides and *Rhizobium* inoculum is not fully worked out. There is a need to work out a safe seed-treatment fungicide-*Rhizobium* inoculum combination that could be used in a wide range of agro-climatic zones in different countries without any harmful effect on the nodulation and nitrogen fixation. The increasing use of systemic fungicides in recent trials on the combination of *Rhizobium* inoculum may not be effective in plant stands where seeds are heavily contaminated or infected with a wide range of seedborne microorganisms and the soil is contaminated with soilborne microorganisms. Hence, a combination of a wide spectrum seed-dressing fungicide and a systemic fungicide may prove better in evaluating their compatibility with a *Rhi-Rhizobium* strain. Studies are needed to work out a safe combination of nonsystemic plus systemic fungicide and resistant strain of *Rhizobium* inoculum to improve both plant stand and nodulation.

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DISCUSSION

M.D. Tedia: Should we treat the seed with seed protectant fungicide before it goes into storage? Would you recommend this practice to farmers?

Is there any work done on compatibility of the application of a mixture of thiram and systemic fungicide on the survival of *Rhizobia?*

V.K. Agarwal: The seed may be treated with thiram at the time of processing before storage or at planting time. But if the seeds go through the humid and rainy season, the treatment of seed prior to storage may be more useful.

The work on the combination of seed protectant and systemic fungicides and *Rhizobium* inoculum probably has not been experimentally demonstrated.

I. Kaliangile: In view of conflicting results concerning the effect of seed treatments on inoculants, do you treat your soybean seeds with fungicide and insecticide routinely?

V.K. Agarwal: We are recommending the treatment of soybean seeds with thiram at a rate of 0.45 percent and the application of *Rhizobium* inoculum just prior to planting. We have found no adverse effect of thiram seed treatment on the effectiveness of *Rhizobium* inoculum. Seeds are not treated with a combination of thiram and insecticide and *Rhizobium* inoculum. However, studies are in progress.

Soilborne Pathogens and Damping-Off of Soybeans

MOHAMED NAGY SHATLA AND J.B. SINCLAIR

The pathology factor in stand establishment of soybeans is a complex one, because soybean seeds and seedlings are susceptible to a wide range of pathogens (7). These pathogens are seed- or soilborne. Because of soilborne pathogens, stand losses can be encountered even with the use of the highest quality planting seed plus a fungicide seed treatment. Many soilborne pathogens are ubiquitous and omnipresent in certain fields, particularly those that have been cropped in soybeans before. However, these pathogens vary and cause economic losses only when conditions are favorable for their development. For example, stand losses up to 100 percent have been observed when soybean seeds were sown in moist soils with temperatures of 35° C or higher in Nigeria (R.J. Williams, personal communication). These losses were attributed to *Bacillus subtilis*. However, soybeans sown in the same area under cooler, dryer conditions, or under a mulch, had minimal losses. Often, however, more than one pathogen may be involved in a damping-off or seedling root-rot complex. Careful laboratory analyses must be made to determine accurately the pathogen or pathogens involved in a disease.

The more important pathogens known to be involved in seed and seedling diseases associated with the soil are (1, 2, 3, 4, 7, 9): among the fungi—*Fusarium* spp. (pre- and post-emergence damping-off, root rot), *Macrophomina phaseolina* (charcoal rot), *Phialophora gregata* (brown stem rot), *Phytophthora megasperma* var. *sojae* (root and stem decay, damping-off), *Pythium* spp. (damping-off and root rot), *Rhizoctonia solani* (damping-off and root rot), *Sclerotinia sclerotiroum* (root rot and stem decay), *Sclerotium rolfsii* (damping-off and stem decay); among the nematodes—reniform, root-knot, soybean cyst, sting and others; and a bacterium—*Bacillus subtilis* (5, 8). Sources of resistance to *P. gregata*, *P. megasperma* var. *sojae*, *Phythium* spp., *S. sclerotiorum*, *S. rolfsii*, root-knot and soybean cyst nematodes have been published (9).

There have been several studies done in Egypt on soilborne pathogens of soybeans (1, 2, 3, 4). One report deals specifically with the soilborne pathogens of irrigated soybeans (6). This research can provide an understanding of the problems of stand establishment in the tropics and subtropics. In this paper we present summaries of studies on soilborne pathogens and damping-off of soybeans made in the Department of Plant Pathology, Menoufeia University, Sheben El-Kom, Egypt. Some of these data come from the studies of S.A. Mohamed.

Survey of Soilborne Fungi

A survey was made of fungi associated with diseased seeds, cotyledons, seedlings, and wilted plants of 15 soybean cultivars from the field during two growing seasons in Egypt. The cultivars used were Bragg, Centennial, Clark, D71-9966, D71-9967, D72-7139, D73-10232, D75-9925, D75-10172, Forrest, Harosoy, Hutton, Lee, Roanoke, and Williams.

The following genera of fungi were isolated on artificial media: *Alternaria* sp., *Aspergillus* spp., *Cephalosporium* sp., *Fusarium* spp., *Mucor* sp., *Penicillium* sp., *Rhizoctonia* sp., *Rhizopus* sp., and *Sclerotium* sp. (Table 1). The fungal genera most frequently isolated were: *Fusarium equiseti*, *F. fusarioides*, *F. oxysporum*, *F. semitectum*, *F. solani* and *Rhizoctonia solani*. Other species isolated were *Aspergillus niger*, *A. quadrotreatus*, and *Rhizopus stolonifer*.

The frequency of isolation of these fungi varied among the cultivars. *Alternaria* sp., *Aspergillus* spp., *Mucor* sp., and *Sclerotium rolfsii* were isolated most often from Bragg, Clark, and Williams and least from D-71-9966 and Lee. *Fusarium* spp. were isolated most often from Harosoy and

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Table 1. The Frequency of Isolation of Fungi from 15 Soybean Cultivars During Two Growing Seasons in Egypt

	Percent recovery[a]							
	Seeds		Cotyledons		Seedlings		Wilted	
Fungus	Average	Mean	Average	Mean	Average	Mean	Average	Mean
Alternaria sp.	16	9	10	7	6	6	6	6
Aspergillus spp. and *A. niger*	7	5	10	6				
Cephalosporium spp.	...	0.3						
Fusarium equesti, *F. oxysporum*, *F. semitectum*, and *F. solani*	77	51	66	3	28	24	80	73
Mucor sp. and *Rhizopus* sp.	20	13	5	13	9	8		
Rhizoctonia solani	28	18	38	25	48	46	21	19
Sclerctium rolfsii	...	0.7	4	2	5	5	2	2
Unidentified	5	3	7	4				

[a] Based on 100 units for each plant part.

Williams and least from D75-9925 and Forrest. *Rhizoctonia solani* was isolated most often from Clark, D71-9967, D73-10232, D75-9925, Lee, Roanoke, and Williams, and least from D72-7139.

PATHOGENICITY STUDIES

The pathogenicity of many of the fungi isolated from diseased soybean tissues was determined by growing soybeans in ten pots of soil inoculated separately with the various test fungi. The pathogencity of *R. solani* and *S. rolfsii* on five Clark soybeans per pot was studied. *Rhizoctonia solani* caused 100 percent preemergence damping-off, and *S. rolfsii* caused 100 percent postemergence damping-off. The following fungi caused pre- and postemergence damping-off (in percentage) on Clark soybeans, respectively: *Alternaria* sp., 71 and 20; *F. equiseti*, 30 and 20; *F. fusarioides*, 64 and 60; *F. moniliforme*, 82 and 55; *F. oxysporum*, 64 and 40; *F. semitectum*, 78 and 50; *F. solani*, 42 and 40; *Mucor* sp; 20 and 20; and *S. rolfsii*, 92 and 100. None of the plants showed symptoms of disease in noninoculated soil.

REACTION OF ELEVEN CULTIVARS TO *FUSARIUM* SPP., *R. SOLANI* AND *S. ROLFSII*

Isolates of *F. fusarioides*, *F. moniliforme*, and *F. oxysporum* from soybean tissues were grown separately on autoclaved barley grain medium. The infected grains were used to inoculate autoclaved soil. Ten pots of soil (replicates) were prepared for each of eleven *Fusarium* isolates. After one month, each pot was planted with five soybean seeds.

At 45 days after planting, the reaction of the plants in the inoculated soil was rated on a scale of 1 to 5 using the following criteria: 1 = plants without symptoms; 2 = stunting of plants, vascular browning up to 2 cm; 3 = stunting of plants, vascular yellowing up to 5 cm; 4 = severe stunting, vascular yellowing more than 5 cm; and 5 = entire plant wilted and/or dead.

A disease severity index was calculated based on Skadow's formula:

$$I = \frac{[aK(K(K-1))]}{2n}$$

where I = the disease severity index, aK = number of plants in each category of infection (1 to 5), K = the type of infection, and n = total number of plants.

The reaction of the eleven cultivars varied among and between the various spp. of *Fusarium* (Table 2). The cultivar with the lowest disease severity index reading in soil infested with *F. fusarioides* was Hutton, which was considered resistant; and the cultivars with the highest readings were D75-10172 and Centennial, which were considered susceptible. For *F. moniliforme* the cultivar with the lowest reading was Centennial, and those with the highest were Forrest and D71-9966. For *F. oxysporum* the cultivars with the lowest reading were D72-7139 and Hutton, and with the highest, Forrest. Lee consistently had a low disease severity index for the three pathogens and was considered the most resistant to them; Forrest and D75-10175 were the most susceptible to the three pathogens.

Table 2. Response of Related Soybean Cultivars to Each of Three Isolates of Fusarium *spp. in Infected Soil*

Cultivar	Disease severity index for each isolate[a] *F. fusarioides*	*F. moniliforme*	*F. oxysporum*
Bragg	13.4	9.3	28.4
Centennial	31.1	2.1	21.8
D71-9966	9.2	14.6	6.7
D71-9967	9.2	43	7.9
D72-7139	9.4	19.7	2.0
D75-9925	16	10	14.5
D75-10172	90	21.9	28
Forrest	22.7	92	33.3
Hutton	5	18.5	2.2
Lee	8.7	6.5	6.7
Roanoke	18.7	25.1	11.4

[a] Based on the formula: $I = \frac{[aK(K(K-1))]}{2n}$, where I = disease index; aK = number of plants in each category (1 to 5) of infection; K = type of infection; n = total number of plants. Ten pots with five seeds each per seed cultivar/pathogen combination were used.

Table 3. Reaction of Soybean Cultivars to Rhizoctonia Solani *and* Sclerotium Rolfsii *in Pots of Soil Inoculated with the Pathogens*

	Mean percentage[a]			
	R. solani		*S. rolfsii*	
Cultivars	Preemergence	Postemergence	Preemergence	Postemergence
Bragg	62	48.2	86.7	100
Centennial	82	100	100	...
D71-9966	78	63.6	90	100
D71-9967	74	77	90	100
D72-7139	42	40	90	100
D75-9925	60	50	100	...
D75-10172	68	64	100	...
Forrest	60	60	90	100
Hutton	60	60	90	100
Lee	70	66.7	90	100
Roanoke	56	58.2	90	100
Control	0	0	0	...

[a] Based on ten pots with five seeds per each cultivar/pathogen combination.

The reaction of eleven cultivars to *R. solani* and *S. rolfsii* was recorded (Table 3). Five seeds of each cultivar were planted in ten each of pots of soil inoculated with either of the test fungi. D72-7139 was considered tolerant to *R. solani* with 42 and 40 percent pre- and postemergence damping-off, respectively. At least one-half of the seedlings of the other cultivars showed symptoms of pre- and postemergence damping-off. All seedlings were considered susceptible to *S. rolfsii.*

Reaction of 25 cultivars to three isolates of *Rhizoctonia solani* seeds of 25 cultivars were planted in pots of soil inoculated with one of three isolates of *R. solani* designated as isolates I, II, and III. There were ten pots of five seeds per each cultivar/isolate combination used. The mean percentage pre- and postemergence damping-off was recorded.

The number of diseased seedlings varied among cultivars and between isolates and the test fungus (Table 4). Isolate II appeared to be the most pathogenic, isolate III the least, and isolate I intermediate. Davis and Gasoy 71 had the lowest number of diseased seedlings and were considered

Table 4. Pre- and Postemergence Damping-Off of Soybean Seedlings of 25 Soybean Cultivars Caused by Three Isolates of Rhizoctonia Solani *under Greenhouse Conditions, Egypt*

	Mean percentage disease per isolate[a]					
	Isolate I		Isolate II		Isolate II	
Cultivars	Pre-emerg.	Post-emerg.	Pre-emerg.	Post-emerg.	Pre-emerg.	Post-emerg.
Bossier	45.6	16.3	68.4	28.9	25.1	11.9
Bragg	50.9	12	68.4	19	31.1	8.6
Calland	31.9	26.1	54.2	30.6	18.1	21.7
Centennial	62.1	30.3	84.1	50	40.5	20.1
Cobb	16.7	10.1	36	16.4	10.6	7.2
Columbus	46.3	20.6	71.7	30.6	24.7	14.5
Crawford	20.2	13.9	48.7	17.5	15.7	10.1
Cutler 71	38.9	27.3	72.5	38.9	19.2	20.5
Davis	8.8	9.4	15.3	12.7	14.5	2.1
D71-9966	17.4	13.4	39.5	18.2	9.2	7.4
D71-9967	40.1	16.3	65.1	22.2	17.1	9.1
D72-7139	15.3	10.1	28.2	15.1	8.6	4.6
D75-9925	59.1	15.1	77.6	27.8	38.6	10.1
D75-10172	60.7	27.3	80.3	44.4	39	17.8
Forrest	49.1	14.5	71.9	20.6	30.2	10.7
Franklin	33.6	27.3	59	36.1	18.7	22.2
Gasoy 17	7.9	6.4	11.7	8.8	3.8	0
Hutton	57.7	22.7	72	27.8	42.2	13.4
Improved Pelican	67.4	37.8	89.8	66.7	49	24.1
Lee	50	17.9	66	26.1	29.5	9.8
Mitchell	25.8	15	37.1	17.7	17.2	10.4
Ransom	21.1	15.3	51.5	24.4	11.9	10.4
Rillito	26.9	17.1	45.5	23.4	12.1	14.5
Roanoke	42.9	15.7	63.4	24.4	19.6	8.7
Williams	48.6	17.3	68.9	21.7	28.7	12.4

[a]Means of five replications (plants).

tolerant to the three isolates. Cobb D71-9966 and D72-7139 were more tolerant of isolate III than isolates I and II. Improved Pelican was the least tolerant, showing the highest numbers of diseased seedlings in both categories; i.e., there was a high degree of preemergence damping-off, and those that survived had a high degree of postemergence damping-off.

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Country Reports

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Bangladesh

MOHAMMAD ABDUL KHALEQUE

Soybeans are a new crop in Bangladesh. The crop was introduced during the 1960s, but no attention was given to its improvement and expansion until 1974. Under a research program of BARI its feasibility as a regular crop was studied and its comparative performance with other crops was observed. The cultivars grown at that time were of long duration (130 to 150 days) and were grown during summer months in competition with major crops like rice and jute. Several good cultivars that were either resistant or tolerant to yellow mosaic virus were collected from abroad and grown in Bangladesh. In 1975 the Bangladesh Coordinated Soybean Research Project was started under the Bangladesh Agricultural Research Council. After that, serious work began on matters like cultivar improvement, cultural practices, and processing. Few farmers had grown soybeans before the project started. With the introduction of short duration cultivars, growing soybeans became popular. The crop can now be found on farmers' fields, on a small scale, and there is prospect of further expansion. But even today only about 2,000 acres (810 ha) have gone under cultivation. A national target of 15,000 acres (6,113 ha) has been set for the second 5-year plan.

Soybean production averages about 16 mds/acre (1,475 kg/ha), which is about 30 percent more than other legumes and 25 percent more than other oilseeds, except peanuts. From the agronomic point of view it is a viable crop for Bangladesh and could fit into the cropping system very well, provided marketing and oil crushing facilities were available. Crushing facilities are not at present located in Bangladesh. But with the recent findings of production potential, industrialists are showing an interest in establishing solvent extraction plants. In fact, some small units of local industry have started refining imported soybean oil. They are interested also in extraction, but due to the lack of an assured supply of soybeans they do not like to start crushing.

PRODUCTION TECHNOLOGY

The area devoted to soybean production is still low, but it is increasing. As regards cultural practices, the land is prepared by the usual method of bullock, plow and ladder. Sowing is done in lines at 30 cm apart. The seed rate is variable from 75 to 85 kg/ha. Harvesting is done by the usual method, cutting with sickles. The crop has not yet found its own place in the cropping list of the country. It has been included in the national plan just as a minor program to test its performance on the farmers' level. The crop is normally grown singly but it is also intercropped with sugarcane. This is grown all the year round; but August sowing gives better seeds for the winter crop, which is sown in December.

Many cultivars are under study. Only two, Bragg and Davis, have been accepted for cultivation. Both these cultivars are semidwarf in habit and require 100 to 115 days for maturity. Such other cultivars as Clark-63, Lee-74, Semmes, and Williams are the prominent ones. All these originated from exotic collections, mainly from the U.S.A.

The following rate of fertilizer is used for soybean cultivation—NPK at 20:60:40 kg/ha (18:54:36 lb/acre). The fertilizer is applied during the final preparation of the land before sowing seeds. The results are really encouraging, and production has increased by 40 to 45 percent.

Native *Rhizobium* is lacking in the soil, so the introduced inoculum is needed for good yield. Local preparation of the inoculum is still in the initial stage of study; however, it is likely that the inoculum will be produced locally on a small scale. The

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preliminary study has brought an encouraging response from the local media. The single species of *Rhizobium japonicum* is used at present. The culture is mixed with the seed before sowing. Its application has proved encouraging, but it will not be acceptable to the farmers until it is manufactured locally.

There is little mechanization in local agriculture, especially in soybean cultivation. However, in the case of large scale production, mechanized sowing, harvesting, and threshing may be practiced to some extent.

Irrigation is required for soybean cultivation because the crop is mainly desirable for the dry winter months, when there is less competition with major crops. If the seeds are sown immediately after the monsoon, thus retaining moisture, a moderate crop is produced without irrigation. For a good crop, irrigation is essential. A limited number of deep tubewells, sunk mainly for rice and wheat, are the main sources of irrigation. Flood irrigation is the usual method of application, since no sprinkler system is available. A water requirement study has not yet been completed. Two irrigations are usually required for a good crop, depending on the type of soil and time of sowing.

Measures to protect plants from disease and insects are essential. The yellow mosaic is the main problem for legumes in Bangladesh. A few cultivars like Bragg, Davis, Lee-74, and Semmes have been found to be moderately tolerant to the yellow mosaic virus. Root rot and stem rot are also damaging to soybeans, but Bragg and Davis are comparatively tolerant. The hairy caterpillar *(Diacrisia obliqua)* does the most damage to soybeans. It is very difficult to control, especially during winter. Handpicking is the only means of control.

Soybean cultivation is still new in Bangladesh. Seed production has been undertaken on a small scale by the Bangladesh Agricultural Development Corporation. Seed is also produced by research organizations for their own needs. Seed maintenance is always a problem because of the fact that seed loses viability very soon unless kept in a dry, cool place. Special storage is essential for preservation.

Average yield in farmers' fields is around 1,475 kg/ha, but on the state farms it is a little higher. The best yields under experimental conditions vary from 2,000 to 2,200 kg/ha, with potential yield up to 2,800 kg/ha.

The cost of production per hectare is around $233 (Tk. 2,495.00/ha), which is somewhat high in comparison with the production costs of wheat, $216/ha (Tk. 3,240.00/ha); mustard, $200/ha (Tk. 3,000.00/ha); and gram, $150/ha (Tk. 2,250.00/ha).

ORGANIZATION

The Bangladesh Coordinated Soybean Research Project has been functioning under the Bangladesh Agricultural Research Council of the Ministry of Agriculture since 1974. The Bangladesh Agricultural University, Bangladesh Agricultural Research Institute, Bangladesh Council for Scientific and Industrial Research, and the Sugarcane Research Institute are the organizations participating in this project. The program has no direct connection with either legumes or oilseeds. At present soybeans are grown mainly for protein food. But it is likely that the extraction of oil will be attempted. The number of research personnel now available in Bangladesh for soybean development and the country's requirement of trained specialists have been noted (Tables 1 and 2).

Table 1. Technical Specialists Available

	Total number	Trained	Academic qualification (M.Sc. & Ph.D)
Field stations	20	...	14
Laboratories	10	...	6
Total	30	...	20

Table 2. Requirement for Training of Specialists for 10 years

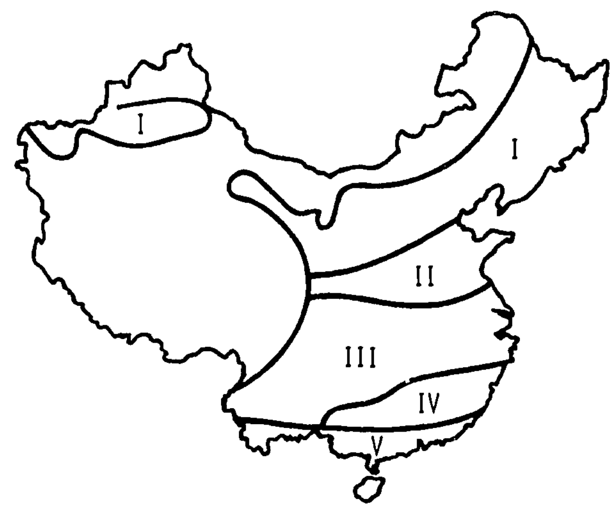
	Total number	Training	Academic study
Field stations			
Agronomy	3	2	1
Breeding	3	2	1
Pathology	2	1	1
Entomology	2	1	1
Irrigation	2	2	0
Post harvest technology	2	1	1
Laboratories			
Food processing	2	1	1
Rhizobium culture	1	1	1
Total	17	11	6

People's Republic of China

CHIN LING WANG

Since the establishment of "New China," the Chinese government has paid the utmost attention to the production of food crops to meet the urgent needs of an increasing population. Although there is a priority for the production of high-yield food crops and only a small area of arable land per capita is available, the soybean production area is being kept to about 7.6 million ha, with an annual production of 7 to 8 million metric tons. In 1975, the area devoted to soybeans was 7.0 million ha, with a production of 7.3 million metric tons; in 1976, 6.69 million ha and 6.62 million metric tons; and in 1977, 6.842 million ha and 7.235 million metric tons. The average soybean yield per ha is just over 1 metric ton. One reason for such low yields is that in most parts of China soybeans are a secondary crop in a rotation system, and are sown mostly after the harvest of winter crops or summer rice. Thus, soybeans grow during the shortest days, and under other adverse conditions. The main soybean-producing area is in the northeast of China, where the yield frequently averages more than 3,000 kg/ha (Fig. 1).

In making full use of the growing season and land in certain localities, Chinese farmers grow soybeans and other crops in diverse patterns of rotation. Such complex rotation systems and other conditions have resulted in a wide variety of uses for Chinese soybeans. For centuries the Chinese people have used soybeans as an indispensable product for food as well as for feed, and have also used soybeans as one of the main sources of edible protein and oil.



I. Spring soybean region

II. Yellow River and Hwai River Valley summer soybean region

III. Yangtze River Valley summer soybean region

IV. Autumn soybean region

V. Multiple soybean cropping season region

Figure 1. Soybean cultivation regions in China.

SOYBEAN MANAGEMENT IN EACH SOYBEAN CULTIVATION REGION IN CHINA

Spring Soybean Region

The main area of this region is in northeast China, where there is only one full season crop each year, and soybeans occupy about 20 percent of the cropping area. Soybeans are planted in late April to early May and mature in late September. On 650,000 ha of soybeans on state farms, all the procedures of production are mechanized. In the brigades of the people's communes soil tillage, seeding, cultivation, and threshing are also mostly mechanized. The main rotation systems are corn-soybeans-millet (or sorghum), and soybean-spring wheat-corn. At the state farms the chief rotation system is spring wheat-spring

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wheat-soybeans. Intercropping of soybeans with corn is prevalent in the provinces of Jilin and Liaoning.

In the northeast, the moldboard plow is usually used in fall plowing, followed by fall harrowing for soybean seedbed preparation. The row width is 60 to 70 cm. In the people's communes, during the course of building planting ridges with a special plow, farm manure is applied and plowed under. Soybeans are planted on ridges to raise soil temperature, and thus promote seed germination. Usually 150 to 200 kg of superphosphate or 100 to 150 kg of ammonium nitrate are applied per ha during seeding. Since soybean seeds in this region develop and mature during the cool fall season, seed quality is fine. Moisture content is around 13 percent, and seeds can be stored safely through the cold winter. In both the state farms and the people's communes, intensive soybean seed grading and selection are undertaken, either by machine or by hand, to clean out cracked and split beans. Under the conditions of drought and a roughly prepared seedbed in spring, the water-holding capacity of the soil may fall below 70 percent and cause a poor stand. In the northern portion of the northeast, occasional deep seeding (over 8 cm), too-early planting and continuous cloudy weather during the planting season can cause the soil temperature to be lower than 10° C and thus result in weak, poor soybean stands.

Weeds are one of the serious problems in the northeast. In the people's communes, two or three hand hoeings plus two or three cultivations are the common methods of weed control. Occasionally, hand hoeing during the seedling stage causes some seedling damage. Formerly, on the state farms, besides the use of cultivation practices, seedling harrowing with special tooth harrows and shallow cultivation prior to planting were also used for weed control. Now herbicides such as Trifluralin are used widely and give favorable results.

About 90 percent of the soybean cultivars in present commercial production in the northeast were developed through hybridization with indigenous cultivars as parents. Soybean cultivars in the northernmost part of this region belong to maturity group 00; those in the middle part belong to group II; and those of the southern part belong to group III. In the past, we concentrated our attention on such breeding objectives as high yield, resistance to lodging, adaptable maturity, better commercial seed quality and high oil content. Now breeding programs on resistance to pod borers *(Leguminivora glycinivorella)*, aphids, cyst nematodes, Cercospora spot, and yellow mosaic virus are also being carried out.

Another important production area of this soybean region is the Loess Plateau in the northern portion of Shansi and Sansi provinces. The adapted cultivars are mostly small-seeded in this dry and unfertile area.

Yellow River and Hwai River Valley Summer Soybean Region

The main rotation system in this region is winter wheat and summer soybean (or summer corn, summer sweet potato, etc.), with two crops a year. First comes the winter wheat. The hot, dry weather forces farmers to give only a light harrowing to the field immediately after the wheat harvest, followed closely by soybean planting to avoid excessive loss of soil moisture and to catch any sudden showers. If soybeans are planted in moisture-deficient soil, they soon lose their viability, and the result is a poor stand. If seeding time is postponed to the middle of June or later, soybean growth might be poor, and delayed maturity would delay the timely seeding of winter wheat. Therefore, better stand establishment and earlier planting are the keys to the improvement of soybean yield in this region. If there is rain during the dough stage of wheat, farmers always try to plant soybeans between wheat rows. This practice not only ensures the germination of soybean seeds, but also promotes early seeding. In this way, soybean yields can usually be raised to 2,500 kg/ha. At present, surface irrigation is prevalent; therefore, seedbed preparation and seeding of a certain portion of soybean fields can be done when timely. In this region storms during the seedling stage cause some seedling damage.

In this region large amounts of farm manure and commercial fertilizer (N and P) are applied on winter wheat, and soybeans take the residue without additional fertilizer. The row width is from 20 to 50 cm, according to the planting tools and cultivars used. Population density is about 50 plants per square meter. Soybeans are harvested when their seeds are still fleshy, dried under sunshine, and threshed with a stone roller pulled by horses or a small tractor. The seeds harvested in late September, when the weather is cool, are normal and can be safely stored at room temperature until the following June. But some of the seeds that are high in moisture content and kept under unfavorable conditions will lose their viability and give rise to a poor stand.

The summer soybean cultivars of this region belong to maturity groups V and VI. Soybeans are planted as late as the middle of June, so their actual growth period is only 110 days.

Cultivars grown in commercial production are mostly farmers' cultivars, but cultivars developed through pure line selection also occupy a large area.

Most prevalent soybean pests here are dodders, aphids, red spiders, and stem borers *(Melanagromyza sojae)*. The most damaging disease is the soybean mosaic virus.

Yangtze River Valley Summer Soybean Region

In this area the frostless season is as long as 250 to 300 days, and day length within the growing season varies greatly. Under such conditions, cropping systems in which soybeans are included are very complex, but soybeans follow winter wheat, winter barley, or winter rape. With a summer crop, two crops in one year is the main rotation system.

Near the urban areas farmers grow spring soybeans, sown around the middle of April and harvested at the middle of June, like green beans, to be used as a fresh vegetable. There is also a large acreage of spring soybeans with a cropping system that incorporates three crops--winter barley or wheat, spring soybeans interplanted between rows of barley or wheat at the dough stage, and autumn paddy rice--in one year. Soybeans planted along the edge of paddy rice fields are also spring sown. Another three-crop system consists of winter crops--early- and middle-season rice and autumn soybeans--in one year. Such complex cropping systems and various natural conditions in this region cause soybeans to be exceedingly diversified in type. Therefore, this region has the most plentiful soybean germplasm resources.

Most spring-sown soybeans in this region belong to maturity groups I to III; most summer-sown soybeans, to maturity groups VI to VII; and most autumn-sown soybeans, to maturity groups VIII to IX. In commercial production, except for a few cultivars developed through pure line selection, most cultivars are farmers' cultivars.

Summer soybeans mature around the middle of October. The selected and dried seeds can be safely stored under room temperature until the following May without losing viability. On the other hand, the maturation period of the early spring-sown soybeans coincides with the hot, rainy season. Seeds developed under such conditions are poor in quality. Some of the small brown- or black-seeded spring-sown cultivars may produce acceptable seeds that can be used for seeding the following spring if they are kept in sealed containers. But seeds of the large-seeded spring-sown cultivars are exceedingly poor in quality. To overcome this problem, farmers traditionally set a seed nursery and postpone the date of seeding to early July, so that the seeds can develop and mature under the cool, dry autumn conditions. Although yield is heavily reduced because of late planting, seed quality is highly improved. Experimental results show that it is worthwhile to propagate such spring soybean seeds every year in the northeast.

In this region soybean rust and soybean mosaic virus, as well as pod borers *(Etiella zinckenella)*, red spiders, and stem borers *(Melanagromyza sojae)* all cause damage.

Autumn Soybean Region

In the southern part of China, on the less fertile, water-deficient land, a rotation system of three winter crops--early- or middle-season rice and autumn soybeans--is favored. The autumn soybeans are sown in late July to early August and harvested in early November. One kind of autumn soybean has small (8 to 10 g per 100 seeds) brown or yellow seeds with a bloom on the seed coat. The seeds are mostly of an indeterminate type and have more branches than is typical. Before rice is harvested and after surface water is drained from the field, soybean seeds are broadcast among the rice plants. At the time the rice is harvested, the bean seedlings are 6 to 7 cm high. Another kind of autumn soybean is a yellow or green large-seeded (15 to 16 g per 100 seed) type. After the harvest of the early- or middle-season rice in late August, soybean seeds are planted near the rice stubble without covering it with soil. With high temperature, sufficient moisture, and shallow seeding, the seeds germinate and become young seedlings within 4 to 5 days. The cultivars of these two types of autumn soybean are typically short-day and belong to maturity groups IX and X. But under the short-day length of late fall, their growing period is about 100 days. The plants are 50 to 60 cm high, and the average yield is 600 to 700 kg per ha.

Farmers in this region traditionally pay a great deal of attention to seed selection, cleaning, and storage. The selected clean seeds are desiccated to a degree (water content below 11 percent) at which they can be beaten easily into pieces. The desiccated seeds are stored in glazed small-mouthed jars and sealed to be stored over the hot, moist summer. The jars are opened early the next fall within 10 days before seeding. It is observed that seeds of small-seeded types store better.

Multiple Soybean Cropping Season Region

In the southernmost portion of China, there is a frostless belt where the mean winter temperature is as high as 18° to 20° C. Therefore, winter soybeans can be sown in late December and mature from mid-April to early May. In commercial production, spring soybeans that are planted from mid-February to early March and mature from mid-May to early June are dominant and prevalent, and the yield per unit area is also as high as 1.5 mt/ha. In addition, in commercial production, summer-sown soybeans are sown in the middle of May and harvested in the middle of August, and autumn-sown soybeans are planted in mid-July (after rice) and harvested in early November. The smaller variation in day-length throughout the year allows some winter and spring soybean cultivars of maturity groups V and VI to be sown the year around. Those autumn soybean cultivars belonging to maturity groups IX and X, and summer soybean cultivars belonging to maturity groups VII and VIII, cannot be used for winter and spring sowing because of their prolonged growth period.

Winter is a dry season in this region so winter soybeans must be irrigated frequently. Pod borers *(Etiella zinckenella)* are severely destructive and must be controlled with several applications of insecticide.

Egypt

SERAG EL-DIN SAID YOUSEF

Soybeans were introduced in Egypt in 1973 and put under intensive study by the Ministry of Agriculture, which sought to find the cultivars most suitable to be grown under local environmental conditions (Table 1).

Soybeans are used (1) as seeds for planting the following season; (2) as a source for extracting oil, after which the residue is used as a nutrient in poultry projects; and (3) as an extender to be mixed with meat to reduce food costs.

The total area devoted to the production of soybeans was 82,679 feddans in 1980, and the total yield was 87,224 tons for an average yield of 1,050 tons per feddan. The cultivated area was largest in the northern regions, moderate in the Sinai governorate, and smallest in the other regions. Soybeans were not grown at all in the Kena, Aswan, Elwahat, or Red Sea governorates.

The cultivated area in soybeans represented 1.5 percent of the 5.5 million feddan total cultivated area in Egypt in 1980.

METHODS OF LAND PREPARATION AND SOWING

The land is divided into ridges 60 to 80 cm apart. It is given a relatively high amount of water and left until it reaches a suitable moisture content, that is, until it contains the specific degree of moisture needed for germination. The seeds are very sensitive to water, so the land is rapidly irrigated with a small amount of water before the seeds are sown.

Seeds are sown in hills 5 to 10 cm apart at a rate of 3 to 4 seeds per hill. Approximately 30 to 35 kg of seed are planted per feddan of land.

Seeds are planted between March 15 and April 1 and harvested 120 days later. Samples of seed can be submitted to the seed testing station just after harvest to determine their purity and viability.

Soybeans are sown in a crop rotation pattern, sometimes as an intercrop.

Clark, Williams, and Calland cultivars are imported from the United States. About 30 percent of the seed used to be imported; however, since 1980, we have been largely depending upon local production.

The area that has been cultivated and planted in each soybean cultivar in 1980 is given in Table 2. The largest area was planted with Calland in the middle part of the Delta, that is, in Menoufeia, Sharkia, Gharbia, and Kafr El Sheikh governates.

Rhizobium inoculant is mixed with the seed with a small amount of water. The inoculant that is used is imported from Norway in the form of 20 gm tablets and is called JIFFY-7 700.

Planting is not mechanized in Egypt, except on state farms.

Since soybeans are very sensitive to water, special precautions are taken in the irrigation process. The crop is irrigated from four to six times during the period of growth (Table 3). The irrigation process, which uses water from the River Nile, occurs rapidly.

The amounts of fertilizer recommended in the preparation of land for soybean cultivation are shown in Table 4.

The plants must be protected from blight, which is common and causes great damage; from rot putrefaction, which decreases germination; and from certain pests. *Graglotalba graglotalba* infests the crop that is planted after potatoes. *Pordonia latura* (cotton worm) is common and causes a great deal of damage. *Aipes menfra* causes less damage.

Although about 30 percent of our seed supply used to be imported from the United States, Taiwan, and Southeast Asia, we now depend mainly on local production. The soybean development program under the Ministry of Agriculture, the Oil Seeds Institute, and the universities provide the needed seed.

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Table 1. Production of Soybeans in Egypt, 1975 to 1980

Year	Area (feddans)	Total production (t)	Average production (feddans)
1975	8,505	4,808	0.565
1976	16,959	11,407	0.673
1977	33,128	26,496	0.800
1978	81,713	78,828	0.965
1979	99,196	96,123	0.970
1980	82,679	87,224	1.050

Table 2. The Area and Location for Growing Various Soybean Cultivars in Egypt

Cultivars	Area (feddans)	Regions
Williams	18,531	North Delta
Calland	33,386	Middle Delta
Clark	30,762	Elmenia and Assuit governorates
TOTAL	82,679	

Table 3. Recommended Irrigation Schedules

Irrigation	Times
First	After 17 to 22 days
Second	After 32 to 42 days
Third	After 47 to 62 days
Fourth, etc.	Every 15 days thereafter

Table 4. Recommended Amounts of Fertilizer for Soybeans in Egypt

Fertilizer	Amount/feddan	Date of application
Phosphate	100 kg	Before sowing
Nitrogen	60 units:	
	15 Units	Before first irrigation
	30 Units	Before second irrigation
	15 Units	Before third irrigation
Potassium	50 kg	Added during the growth period

The General Seed Department, through seed testing stations on state farms throughout the Republic, determines seed purity and viability after harvest. Farmers obtain tested seed from the Ministry of Agriculture.

Average farm yields are as high as 1 ton per feddan, and the best yields obtainable under experiment station conditions reach 1.5 tons per feddan.

Soybeans are a profitable crop for the farmer. The Ministry of Agriculture pays half the farmer's production costs to encourage soybean cultivation. The farmer receives about Ŀ200 per ton.

CONSTRAINTS

Farmers are not aware of the ideal method of cultivation. They are used to maize rather than soybeans. The harvesting method used leads to seed breakage, which ruins the seeds. The cotton worm (*Pordonia latura*) causes great losses. Soybeans are still a new crop, but we expect to increase the cultivated area.

ORGANIZATION

The General Seed Department, under the Ministry of Agriculture, is associated with the Oil Seed Institute. Laboratories are found in the seed testing stations and on farms throughout the Republic. Work on soybeans requires competent nationals with scientific degrees and professional training. To date, three of our men have been trained at the University of Illinois at Urbana-Champaign.

India

PREM SWAROOP BHATNAGAR
AND HARIHAR RAM

Soybeans are recognized as a potential food crop to bridge the gap between the national need and the availability of protein, as well as oil, in India. With a coverage of approximately 6 lakh hectares in 1981-82, plans to exploit this crop fully during the Sixth Five-Year Plan are being made. The crop (mainly black-seeded) has long been grown in India in the northern hills and other scattered pockets under various names, such as Bhatmas, Kalitur, and Bhat. Recognizing the vital importance of a cheap vegetable source of high quality protein (40 percent) and oil (20 percent), Mahatma Gandhi advocated the popularization of soybeans among the masses. Since soybeans provide an ideal combination of high protein and oil content, they are rightly said to be two crops in one. Moreover, they produce roughly 2.5 times greater yield than other pulse crops (Table 1) and have about double the quantity of protein.

If a new crop is to succeed in the conventional cropping pattern of the country, such problems as disturbance of the commodity balance caused by physical displacement of important crops as well as relative agricultural feasibility and economic viability must be solved. In addition, further study is needed on matters of direct or indirect impact, such as cultivar identification, genotypic improvement, and optimum crop demand for remunerative production. To overcome these problems, integrated research into the production and development of soybeans in India is being undertaken.

SOYBEAN RESEARCH

Encouraged by the promising results of systematic studies at Pantnagar and Jabalpur in 1963 using soybean cultivars from the U.S.A., in 1967 the Indian Council of Agricultural Research launched an interdisciplinary, multilocational, coordinated research project on soybeans. The headquarters of the All-Indian Coordinated Research Project on Soybeans, at Pantnagar, initially had three main centers and six subcenters. However, during the Fifth Five-Year Plan, the project was expanded to five main centers and twelve subcenters to cover different agroclimatic regions of the country. In addition, soybean research is voluntarily conducted at various locations (Figure 1).

The research under the project has led to the understanding of genotype-environment interaction for maximum exploitation of the genetic potential of soybeans for higher yields (and protein and oil content) by providing appropriate management at different stages of plant growth.

The main objectives of the Coordinated Research Project on Soybeans have been (1) to identify and develop suitable cultivars adaptable for the different agroclimatic zones of the country; (2) to develop cultivars resistant to yellow mosaic virus and *Rhizoctonia*; (3) to breed short-duration cultivars for companion cropping with cotton and maize; (4) to improve indigenous cultivars like Type 49 for yield and oil content, or to incorporate the good germination qualities of indigenous cultivars into high-yielding exotic cultivars; (5) to develop production technology to make possible profitable yields in problem soils; (6) to cultivate practices for companion cropping of soybeans with maize, cotton, finger millets, and other smaller millets; (7) to develop a Rhizobial culture with a longer shelf-life, wider adaptability, and greater efficiency; (8) to develop suitable harvesting and threshing machinery; (9) to study the production economics of soybeans as compared with other competing crops, such as moong (*Vigna radiata*), ragi (*Eleasine coracana*), and other millets, as well as the

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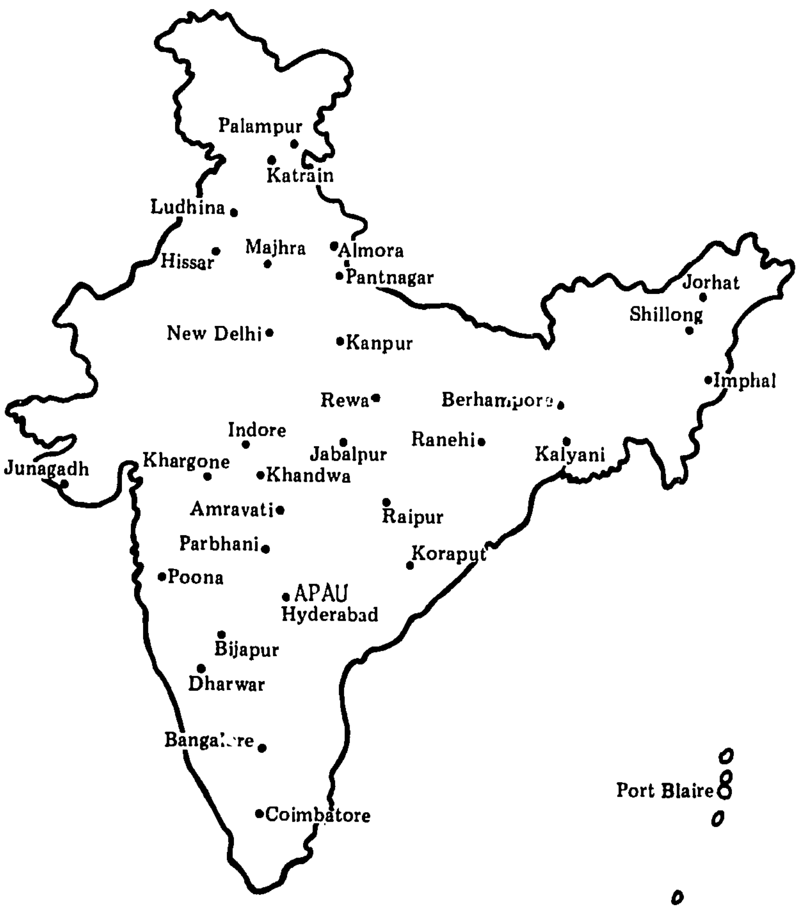

Figure 1. Centers involved in the All-India Coordinated Research Project on Soybeans.

economic viability of companion cropping with possible summer crops; (10) to develop soya-based food products for efficient home as well as commercial use; and (11) to maintain surveillance over new diseases and pests and to develop economical control measures.

VARIETAL IMPROVEMENT

The cultivar development program started in 1963 with the introduction and testing of improved cultivars from the U.S.A. Some of the U.S. cultivars yielded about 30 quintals per ha, that is, almost three times that of traditional kharif pulses. One of the promising introductions was Bragg, which was released for general cultivation in 1968. With its spreading cultivation new problems regarding diseases, such as yellow mosaic, rust, *Rhizoctonia*, and pod blight, as well as problems associated with seed germination and viability, were recognized, and extensive breeding programs were initiated to overcome these problems. These efforts were intensified throughout the country, particularly at Pantnagar, Jabalpur, and Delhi. This vigorous approach led to the development of a series of cultivars suited to various agroclimatic zones of country (Table 2).

Evaluation of the world collection of soybean germplasm, totaling over 4,000 entries, resulted in the identification of sources of resistance to yellow mosaic (UPSM 434, *G. formosana*), rust (Ankur), bacterial pustule (Bragg), and *Macrophomina*. Resistance to yellow mosaic, which is a hazard to soybean cultivation in certain areas, has been found to be genetically controlled. Further research has facilitated the breeding of cultivars resistant to these diseases (1). Attempts at utilization of these sources in breeding improved cultivars have been encouraging.

Studies in seed production and storage have led to the identification of regions at higher altitudes (3,000 to 5,000 feet above sea level) that are more suitable for the production of seeds with a low incidence of diseases.

PRODUCTION TECHNOLOGY

Studies have demonstrated that a successful crop of soybeans can be grown with a relatively low fertilizer level (N.P.K. = 20:60:40 kg per ha) provided the seeds are treated with *Rhizobium*. A depth of 3 to 5 cm has been found to be optimum. Premonsoon planting has been found better than postmonsoon sowing because of the difficulty of establishing a stand. A plant population of about 0.3 million per ha is good for rainy season planting, whereas, for spring planting, the optimum plant population has been found to be 0.5 to 0.6 million per ha.

The monsoon season crop requires one preplanting irrigation and one or two more irrigations during the pod-filling stage. If the monsoon ends earlier, surface drainage is reported to be essential for good growth (4). The profitability of mixed cropping of soybeans with millets, pulses, maize, and cotton in the plains has been demonstrated. Mixing Rhizobial inoculant with seed prior to planting, from the last week of June to the end of July, in rows at 45 to 60 cm with plants 2 to 5 cm apart, has yielded good results.

Efficient strains of *Rhizobium japonicum* have been identified and evaluated, and commercial production of bacterial cultures for soybean cultivation has been undertaken. Thus local sources of *Rhizobium* culture are available for soybean cultivation in India.

PLANT PROTECTION

A survey of insects and diseases has resulted in the identification of diseases and pests of economic importance. The important diseases are soybean mosaic, yellow mosaic, bacterial pustule, anthracnose (pod-blight), and Rhizoctonia aerial blight. The important insects are pea stem fly, white fly, thrips, Bihar hairy caterpillar, and girdle beetle. Newly-developed cultivars possess resistance to most of the diseases, namely, rust, bacterial pustule, and yellow mosaic. The search for sources of resistance to insects is continuing; however, some effective spray schedules have been standardized. Yellow mosaic and most of the insects attacking foliage can be controlled by following a spray schedule of a combination of 0.1 percent thiodon and 0.1 percent metasystox starting at 20 to 25 days after planting and repeated at 10-day intervals until pod formation. Effective control of the stem borer has been achieved by the use of Thimet-10 granules at 10 kg per ha.

SOYBEAN DEVELOPMENT

Efforts to develop the crop in India have been encouraging. An unbiased study of various economic aspects of soybean production has shown that soybeans will have no adverse effect on other important crops and will not displace any crop of importance. In fact, the cultivation of soybeans will allow considerable utilization of 1,032,000 ha of land left fallow during the summer (10). This area should produce about 2,484,000 tons of soybeans to provide a stable oil supply. The export of defatted soybean meal will also be extensive. Ecologically, soybeans can be grown successfully in any area where maize can be grown, and because of their tolerance for drought, soybeans have a definite edge over maize. The availability of soybean cultivars with varied photo- and thermosensitivity and short duration provide a broad scope for their cultivation throughout the country.

With the availability of indigenously developed cultivars, backed by a sound seed production infrastructure and the establishment of soya-based industries, the crop is becoming popular, particularly in Madhya Pradesh, the Bhabhar area, and the Rohilkhand Division of U.P. Locally organized marketing facilities have begun to gain momentum, particulary in Haldwani of U.P., which has led to the increasing cultivation of soybeans in the Bhabhar and adjoining areas of U.P. Traditional rice growers in the area are now shifting to soybeans because soybeans require fewer inputs like fertilizer and irrigation and because they bring a profitable price (about 250 rupees per 300 quintals) on the local market. The crop in the Bhabhar is bush green, bumper, and free of yellow mosaic. The yields are often 25 quintals per ha. In the Bareilly district of U.P., maximum yields of 3,742 kg per ha were obtained in demonstrations organized by SPRA under village programs from 1979 to1980(9).

With the meager beginning of about 300 ha of soybeans in 1968, the coverage in soybeans has steadily increased to about 600,000 ha in Kharif in 1980-81. Nevertheless, progress has not been commensurate with contemplated targets (Table 3). The targets during the Sixth Five-Year Plan may be fixed at 25 lakhs. To achieve this, an ambitious program is being formulated.

Seed treatment with Thiram at 3 gm per kg is effective in protecting the seedlings from conventional rots, and it results in a better stand. The application of 2.5 kg Zinab per ha at 50, 60, and 70 days after planting (8) has been found to control rust caused by *Phakospora pachyrhizi*.

FOOD USES AND UTILIZATION PATTERN

Over the last decade, increased attention has been devoted to the search for nonconventional protein and protein-calorie sources to augment global food supplies. It is easy to envision vegetable protein and calorie sources as filling this gap and fitting into our dietary pattern. Soybeans outrank all other natural sources since they contain approximately 40 to 42 percent protein and 20 to 22 percent oil and have a higher yield potential than any other pulse crop.

Among vegetable proteins, soybeans are an excellent source of high quality protein. Thus, they can fill the animal protein gap to a great extent. Soybean oil is highly polyunsaturated and thus a boon to combating heart ailments. Besides all this, soybeans do not support the production of aflatoxins.

The great potential soybean protein has for meeting the protein requirements of man is illustrated by the fact that 1 acre of soybeans will provide enough protein to sustain a moderately active man for 2,224 days, as compared with 1 acre of wheat, which will meet the protein requirements of a man for 877 days and corn, 354 days. If 1 acre of land is used solely to raise animals for protein, it will provide only a 77-day protein supply for one man.

Soybeans have a wide range of uses, namely, for human food, animal feed and raw industrial materials. Soybean oil products in the United States include salad and cooking oil, hydrogenated oils, and margarine. In Japan, soybeans take many forms, namely, tofu, misa, natto, kori tofu, soy sauce, kinak, and others. In India, various soybean products similar to conventional dishes have been standardized at G.B. Pant University of Agriculture and Technology, Pantnagar; J. Nehru Krishi Vishwa Vidyalaya, Jabalpur; University of Agricultural Sciences, Bangalore; CFTRI, Mysore; and other places (2, 3, 7). Products of oriental origin as well as those similar to western products like bread, biscuits, cake, pastry, and soy milk have become very popular, and various kinds of manufactured products, namely, Nutri-nuggett, Protein-plus, Protesnoc, Shakti-ahar, and Soya-stattu are available. Commercial organizations have been making extrusion products, using the Wenger X-25 Extrusion Cooker and full-fat and defatted soy flour. A considerable quantity of

Table 1. Average Yield of Soybeans and Other Pulses under the Same Conditions in India

Crop	Yield (kg/ha)
Soybeans	2,960
Pigeonpea (Arhar)	1,660
Blackgram (Urd)	1,040
Cowpea	1,040
Greengram (Mung)	880

SOURCE: Singh and Saxena, 1975.

Table 2. Improved Soybean Cultivars for Different Agro-climatic Zones in India

Agro-climatic zones	Cultivar recommended	Days to maturity	Yield (quintals/ha)
Northern hill zone	Bragg	120	25-30
	Lee	110	20-25
	UPSM-19	105	20-25
Northern plain zone	Bragg	120	20-30
	Ankur	125	20-30
	PK-71-21	120	25-35
	UPSM-19	105	20-25
Central zone	Bragg	115	20-30
	Ankur	120	20-30
	JS-2	105	20-25
Southern zone	Improved Pelican	110-120	15-20
	Hardee	110-120	15-20

SOURCE: Singh and Saxena, 1975.

Table 3. Targets and Achievements of Soybean Production in India

State	1978-79[a] Area (ha)	1978-79[a] Production (tons)	1970-80[a] Area (ha)	1970-80[a] Production (tons)	1980-81[a] Area (ha)	1980-81[a] Production (tons)
Madhya Pradesh	232,562 (200,000)	232,000 (211,400)	414,341 (400,000)	R.A.[b] (51,400)	447,606 (480,000)[c]	R.A. (375,000)
Uttar Pradesh	68,689 (130,000)	60,326 (76,400)	75,866 (137,500)	36,121[d] (70,400)	131,745 (175,000)	R.A. (106,400)
Karnataka	1,181 (3,000)	588 (2,400)	1,296 (3,000)	R.A. (2,400)	... ...	... ...
Bihar	655 (3,000)	500 (2,400)	R.A. (3,000)	R.A. (2,400)	R.A. (5,000)	R.A. (4,000)
Himachal Pradesh	4,000 (3,000)	R.A. (2,400)	(3,900) (3,000)	5,850 (2,400)	4,000 (6,000)	6,000 (4,800)
Rajasthan	...	...	...	...	R.A. (2,000)	R.A. (1,600)
	307,087 (339,000)	293,414 (395,000)	491,747 (556,500)	36,121 (139,000)	579,351 (668,000)	.. (491,800)

SOURCE: Government of India, Ministry of Agriculture, Directorate of Oilseed Development, Hyderabad.
[a]Figures in parentheses indicate targeted area and production.
[b]R.A. = Report awaited.
[c]The state has a coverage target of 6,000,000 ha.
[d]Because of drought, the yield and total production have gone down.

soybeans is being solvent-extracted; the cake is exported for animal feed, and the oil is used for hydrogenated fat production.

The pattern of soybean utilization in India is based on both Japanese and American types. Thus, the utilization of whole beans as well as the manufacture of various food products from soybeans is envisaged. The use of soybeans in oriental dishes popular in India has been successfully demonstrated. Therefore, Japanese patterns will help us to formulate food products that fit into our dietary pattern. As a result of considerable research done in India on the food uses of soybeans, two books describing a total of over 200 recipes have been published (2, 7).

The main problems in expanding the area under soybeans in India are the limited market and the uncertainty of the financial return. Facilities for the procurement of soybeans in small quantities from individual growers and for supplying processing units would go a long way toward solving these problems. The creation of processing facilities for various soybean products has been proposed for more successful exploitation of the crop. In addition, attempts are being made to popularize home use of this protein-rich source in various forms.

FEED USES OF SOYBEAN IN LIVESTOCK AND POULTRY INDUSTRY

There is an acute need for nutritious feed for our developing livestock and poultry industry. In contrast to the total requirement of approximately 95.4 million tons of feed concentrate, there are only about 13.6 million tons available from all sources. Thus, a gap of 81.8 million tons has to be bridged. To achieve augmented milk production, more feed concentrates will be needed. In terms of price, soybean concentrate is comparable to other commonly used feed concentrates in India, but on the basis of protein per kilogram of concentrate, it is cheaper. For several decades soybeans have been used as animal feed in the Western Hemisphere, and their effectiveness in increasing the productivity of raising animals has been amply demonstrated.

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Malaysia

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Soybeans (*Glycine max* (L.) Merr.) are an excellent source of high quality protein and have a wide variety of uses for both human and animal nutrition. Soybeans can have wide geographical adaptation provided appropriate breeding work is done. For years Malaysia has imported an appreciable quantity of soybeans.

It has been estimated that the local consumption of soybeans per capita per year averaged 5.3 kg for the years 1941 through 1973 (3). Assuming an annual population growth rate of 2.7 percent and a per capita consumption rate of 5 kg, the projected demand for 1980 would be 71,000 metric tons.

In spite of their importance, soybeans have been grown in Malaysia only on a trial basis. One of the main problems of growing soybeans is the lack of locally adapted high-yielding cultivars with desirable grain quality. Plant breeding for food crops and vegetables has been almost completely disregarded in Malaysia, except for rice. The Fourth Malaysia Plan requires food self-sufficiency, and plant breeding for food crops is the key to reaching this goal.

To foster plant breeding in Malaysia, soybeans have been selected as a model crop for three reasons:

1. Almost all soybeans and their products now in use are imported (for a total import value in 1977 of 70 million Malaysian ringgitt);
2. There is ample evidence in the literature that soybeans are adaptable to the humid tropics (6, 8, 9, 10, 11), and the potential for soybean growing in Malaysia has been shown in trials conducted on introduced cultivars by the Malaysian Agricultural Research and Development Institute (MARDI), the Rubber Research Institute of Malaysia (RRIM), and the Universiti Malaya (see Historical Background).
3. In other Southeast Asian countries where soybeans are grown on a large scale, the locally bred cultivars have been found to be superior to introduced cultivars (9).

Soybeans could be grown in Malaysia for two purposes: (1) to be used as an intercrop in plantations, for example, with immature rubber and oil palm trees to give a quick cash return, which would be particularly important for small landowners; and (2) to be used in rotation with rice and other crops.

Five institutions—the Malaysian Agricultural Research and Development Institute (MARDI), the Rubber Research Institute of Malaysia (RRIM), Universiti Kebangsaan Malaysia (UKM), Universiti Malaya (UM), and Universiti Pertanian Malaysia (UPM)—agreed in 1977 to establish a five-year Joint Malaysian Soybean Breeding Project. The target of this project was to develop cultivars that could be grown by farmers and compete in price and quality with imported soybeans. After careful discussion, the five institutions developed the coordinated project described in detail in this paper by the five participants. The project uses classical crossbreeding methods and mutation breeding. There is only minimal overlap in the five-partner program.

The project takes into consideration the individual characteristics of the five institutions, their approaches to soybean cultivation, their needs for genetic research, their facilities for research, their experiences with growing introduced cultivars, and their available personnel. There is a free flow of information and breeding material among the partner institutions.

It is hoped that the joint Malaysian effort can be linked with international activities in the field of grain legume growing in Southeast Asia. Efforts have been started to develop close association and coordination with (1) the current joint

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FAO-IAEA Coordinated Research Program on the Use of Induced Mutations for the Improvement of Grain Legume Production in Southeast Asia, (2) the planned FAO project known as Food Legumes and Coarse Grains Development in the Humid Tropics of Asia, and (3) the International Soybean Program.

HISTORICAL BACKGROUND OF SOYBEAN CULTIVATION IN MALAYSIA

Records of organized soybean research in Malaysia are relatively scant. F.G. Spring (12) reported in 1924 that there were no records of any soybean cultivation. Recently, however, there have been reports of soybean trials of introduced cultivars under local conditions. As in every trial, the yields obtained from relatively small plots and extrapolated to hectares result in considerably overestimated yields. This fact should be kept in mind when considering the figures in the statements that follow.

At Universiti Malaya, Chan (2) evaluated six cultivars and found that Palmetto produced the highest yield, 2,120 kg per ha. Later, Yap and Tan (15) tested 25 cultivars imported from Taiwan and reported yields ranging from 364 to 3,820 kg per ha. Of those cultivars available in Malaya and others imported from AVRDC (Taiwan) and IITA (Nigeria), a total of more than 100 cultivars were tested recently by Funnah and Mak (7), and yields were recorded ranging from 345 to 3,286 kg per ha.

Research by RRIM has indicated that soybeans could serve as a suitable intercrop with rubber (4). Among the cultivars tested, those that yielded more than 2,000 kg per ha include the tall cultivars Acadian and Calland and the short cultivars KS 437, 64-64, 66D-20, and 66D-16 (5).

The MARDI research programs cover studies on agronomy, crop protection, processing, and varietal evaluation including international programs such as INTSOY and SEARCA (1). As part of the cultivar-improvement program, a large number of cultivars and lines have been introduced and tested at several locations. A number of cultivars have been found to be promising in terms of yield and seed size; however, cultivar performance tends to vary considerably with location and season.

Attempts by Sime Darby Plantations in Pilmoor Estate to identify suitable cultivars for commercial production indicated that Clark 63, KE 32, and Palmetto were the best available (13). However, many production problems, such as poor seed quality, weeds, pests, and rust, were encountered, and the project was discontinued.

Soybean cultivation undertaken in Malaysia has been limited to testing and selection of promising foreign cultivars for direct utilization under local environmental conditions. Therefore, there is a need to use modern techniques to breed cultivars adapted to specific conditions in Malaysia.

MARDI SOYBEAN BREEDING AND EVALUATION PROGRAM

MARDI is involved in soybean germplasm collection, cultivar evaluation, and crop protection studies.

Germplasm Collection

In 1976, 29 accessions from three countries were available in MARDI's soybean germplasm collection, and in 1977, 41 cultivars from four countries were added. Recently, an addition of 50 more cultivars was made. These introduced cultivars will be maintained and screened for yielding ability, photoperiod insensitivity, resistance to shattering, seed quality, resistance to major diseases and pests, and desirable plant architecture. Cultivars that do not perform satisfactorily will be discarded and new materials will be introduced into the collection for similar screening.

Varietal Evaluation

Due to environmental variations in different locations and seasons, MARDI carried out various trials in its many research stations throughout the country. Most of the materials tested were from the United States, SEARCA, and Taiwan. The advanced varietal trials carried out on selected promising cultivars have shown that overall yields of each cultivar are not consistent over locations and seasons. However, a number of cultivars were selected as parents for the hybridization program.

In 1978 cultivar evaluations were carried out--two in Serdang and one each in the states of Trengganu and Kelantan. Orba, L-114, and Clark 63 were evaluated for four years in Serdang. In 1976 and 1977, these cultivars had higher yields (greater than 1 mt per ha) than in the other two years. Bossier and Jupiter were evaluated for only three seasons, and yields reached more than 1 mt per ha in 1977 and as high as 2 mt per ha in 1976. Bossier did not show consistent yields, but Jupiter maintained yields at about 1 mt per ha (Tables 1 and 2).

Table 1. Soybean Advanced Varietal Trial at Serdang, Malaysia, First Season, 1978

Entries	Yield (mt/ha)	100-seed weight (gm)	Plant height (cm)
Palmetto	0.87	14.74	79.2
Orba	0.64	14	76.88
No. 29	0.62	7.66	89.21
Clark 63	0.55	16.98	51.78
KE 32	0.54	14.01	69.25
Improved Pelican	0.47	12.67	81.15
TK 5	0.45	16.57	52.75
L - 114	0.41	16.49	60.6
TTKS	0.41	16.15	54.03
CES 434	0.38	11.67	90.9

Source: Joint Malaysian Soybean Breeding Project, First Annual Report (1978).

Table 2. Soybean Advanced Varietal Trial at Serdang, Malaysia, Second Season, 1978

Entries	Yield (mt/ha)	100-seed weight (gm)	Days to maturity	Plant height (cm)
Acadian	1.02	9.33	89	55.3
BM 50	0.68	13.16	91	35.4
BM 51	1.25	16.98	90	25.4
BM 55	0.49	10.44	82	28.8
BM 101	0.78	11.35	82	43.5
G 8377	0.73	10.2	87	49.1
G 8529	0.9	10.1	89	53.7
G 8260	0.65	15.16	87	32.2
No. 1248	0.92	14.92	91	51.5
No.452	1.04	7.89	71	40.7
66D-14	0.97	15.2	88	32.5
66D-16	0.94	15.62	88	35.9
Dung Sum Black	0.77	7.98	79	51
SY-2	0.53	14.11	85	36.3
Tai Ta	0.9	12.85	81	40.7
Palmetto	0.74	11	85	49.1
Orba	0.82	9.5	83	47.4
Bossier	0.49	12.19	107	37.9
Jupiter	1.19	12.7	104	49.6
Clark 63	0.83	10.67	86	39.5
KS 437	0.4	14.99	86	27.7

Source: Joint Malaysian Soybean Breeding Project, First Annual Report (1978).

Palmetto, which was introduced in 1977, Clark 63, No. 29, and KE 32 showed consistent yields (about 1 mt per ha). TK5, TTKS, CES 434, and Improved Pelican did not produce good yields in the first season of 1978, but their yields were recorded above 1 mt per ha in 1976 and in 1977. In the second season of 1978, a number of new promising entries were included in the evaluation: Acadian, BM 51, No. 1248, No. 452, 66D-14, 66D-16, and Tai Ta were among those yielding about 1 mt per ha (Table 2).

A soybean breeding trial was also conducted in 1978. It was comprised of F_6 seeds and F_8 seeds from AVRDC and three check cultivars, namely, Improved Pelican, L-114, and CES 434. Preliminary results showed that two AVRD lines—GC 50009-5-1 and GC 30192-0-13—yielded as high as CES 434 (2 mt per ha) but lower than Improved Pelican and L-114.

RRIM SOYBEAN BREEDING AND VARIETAL EVALUATION PROGRAM

Two objectives of the RRIM in the Joint Malaysian Soybean Breeding Project are to screen for introduced soybean cultivars that small rubber producers can grow profitably as an intercrop while rubber trees are immature, and to breed new soybean cultivars through induced mutation on a joint program with Universiti Kebangsaan Malaysia (UKM).

Screening of Introduced Cultivars

Data on plant characteristics found in ten tall, ten short, and five vegetable soybean cultivars are shown in Tables 3, 4, and 5. The mean yield of the tall cultivars ranged from 718.68 to 1,714.66 kg per ha (Table 3). Palmetto had the highest yield, followed by Acadian. Both of these cultivars have good potential for large-scale planting. Among the short cultivars, KS 437, with 1,567.19 kg per ha, had the highest yield (Table 4). The yield of the vegetable soybean cultivar was extremely low (Table 5), a result attributable to the relatively small number of branches.

Mutation Breeding

This approach is being undertaken with the cooperation of UKM to complement the conventional breeding method undertaken by MARDI and UM. Two sources of mutagens are employed, gamma rays and ethyl methane sulphonate (EMS).

Early results have shown that viable mutations can be induced through artificial means. Mutant lines with different seed coat color and early flowering and maturity are being evaluated at RRIM.

UKM SOYBEAN MUTATION BREEDING PROGRAM

There are two main approaches in the UKM program: straightforward mutation breeding, which could result in the release of commercially usable cultivars within five years and the creation of viable mutants that could be used in conventional breeding programs by cooperators and others interested in soybean production.

Basic studies are being conducted at present to develop fundamentals for inducing mutations using gamma rays and EMS. Some of the results that have been obtained follow.

Effects of Gamma Rays on Growth Parameters in Soybeans

Three soybean cultivars—Acadian, Palmetto, and Tai-ta Kaisung—with differing seed sizes were subjected to 0, 5, 10, 15, 20, 25, 30, 35, and 40 kilorads of gamma radiation. Four M_1 parameters—percentage of germination, seedling height from ground to cotyledonary node, seedling height from ground to tip of first leaf, and first leaf area—were identified. Cultivar differences were significant (P = 0.01) for all three parameters. Results show that the percentage of germination was not affected by irradiation, while seedling height and area of the first leaf were adversely affected with increasing doses.

Effects of EMS Concentrations and Postwashing Periods on Soybean Growth Parameters

Three soybean cultivars, Acadian, Palmetto, and Tai-ta Kaisung, were subjected to the following treatments: 0, 0.5, 1.0, 1.5, 2.0, 2.5, and 3.0 EMS, and postwashing at four different periods, 6, 12, 18, and 24 hours. M_1 growth parameters—germination percentage, seedling height from ground to cotyledonary node, seedling height from ground to first leaf, and first leaf area—were all inversely proportional to increasing concentrations of EMS. Generally, a 12-hour postwashing period was the most effective for all growth parameters. The results also showed that seed size influences the response to different postwashings and doses of EMS.

In addition to the above studies, mutagen uptake in soybean embryos, mutation frequency, and spectrum in M_2 and subsequent generations are being studied.

UM SOYBEAN BREEDING AND QUANTITATIVE GENETICS PROGRAM

One of the major problems in soybean establishment is determining and characterizing agronomically desirable traits. Many times the recognition of such traits is hampered by the influence of the environment on character expression, particularly on yield, which complicates estimating the genetic potentials of different genotypes. Environmental effects on cultivar performance dictate to a large extent the type of yield characteristics that the breeder must incorporate in his breeding material.

No quantitative studies of the interaction of soybean genotypes and environments have been made under Malaysian conditions. Results of such studies would be useful for defining breeding objectives and strategies.

Varietal Evaluation

The degree of potential genetic improvement within a soybean population depends upon the magnitude of genotypic variations available within that population. The objective of the preliminary screening

Table 3. *Plant Characteristics of Ten Tall Soybean Cultivars*

Entry	Days to maturity	Height at maturity (cm)	Branches/ plant	Nodes/ plant	Pods/ plant	Yield (kg/ha)
Palmetto	85	74.7	5.3	27.3	80.1	1,714.66
Acadian	89	45.5	3.8	24	84.2	1,373.63
Tai Ta	81	36.8	3.7	22	49.8	1,115.91
Jupiter	96	43.7	5.3	31.7	86.7	935.09
Hua Lian 2	90	61	2.9	25.9	56.6	1,196.2
Hua Lian 3	81	47.4	3.6	21.8	47.3	930.85
R-10	96	30.1	3.9	19.9	44.7	892.91
Clark 63	80	35.5	1.8	16	31.2	718.68
N44-92	89	44.5	3.1	20.4	46.5	1,046.18
Calland	80	30.3	3.1	19.4	47.8	1,024.88

Source: Joint Malaysian Soybean Breeding Project, First Annual Report (1978).

Table 4. *Plant Characteristics of Ten Short Soybean Cultivars*

Entry	Days to maturity	Height at maturity (cm)	Branches/ plant	Nodes/ plant	Pods/ plant	Yield (kg/ha)
64-64	71	29.5	3.3	20.8	39.8	863.77
66D-1	82	30.8	3.3	20.5	38	1,079
66D-2	86	27.2	3.6	21.4	40.9	1,123.22
66D-14	86	32.5	2.5	14	36.9	856.7
66D-16	73	28	3.5	18.8	40	1,050.47
66D-20	86	28.3	2.5	15.8	44.3	829.25
KS437	80	29	2.9	17.5	38.3	1,567.19
Disoy	89	39	1.7	17.6	33.9	741.37
L114	95	45.9	4.1	21.5	53.2	1,275.15

Source: Joint Malaysian Soybean Breeding Project, First Annual Report (1978).

Table 5. *Plant Characteristics of Five Vegetable Soybean Cultivars*

Entry	Days to maturity	Height at maturity (cm)	Branches/ plant	Nodes/ plant	Pods/ plant	Yield (kg/ha)
Takii Extra Early	66	14.9	0.2	6.2	12	434.34
Makawashima Green	66	23.2	1.1	10.5	24.3	622.71
Sodefuri Green	66	16.3	0.3	6.4	13.6	337.65
Early Hakucho	66	15.9	0.6	8.9	16.5	466.84
Okuhara Early Green	66	21.3	0.9	8.5	18.3	575.16

Source: Joint Malaysian Soybean Breeding Project, First Annual Report (1978).

trials, then, is to make it easier to select the limited number of genotypes for the genotype-environment interaction studies.

In an initial cultivar trial of 111 entries in 1978 (7), a great variation was observed in grain yield and other important traits, suggesting that sufficient genetic variability was available for developing high-yielding cultivars with a number of other desirable characteristics.

An additional 24 cultivars imported from AVRDC were also tested in 1978. The mean values (based on two replicates of a 2.44 x 3.66 m plot) of the various traits were presented in the First Annual Report, Joint Malaysian Soybean Breeding Project. However, it was noted that none of the new entries yielded better than Palmetto, a check cultivar used. In general, high yielders also appeared to be tall.

Genotype-Environment Interaction Studies

Twenty cultivars representing a relatively wide variation in yield and other agronomic characters were selected from this study. There was a significant genotypic difference among lines tested.

Both Palmetto and L114 are among top yielders and can be considered standard cultivars for purposes of comparison in the future breeding program for yield improvement. GC 30238-3-22 had the highest mean grain yield (1,424 kg per ha), whereas Acc. No. BM 41 had the lowest mean yield (1,012 kg per ha) across environments. The range in environmental grain yield means was a result of the diversity of the environments used in this study. The mean for the highest yielding environment was almost nine times that of the lowest yielding environment. However, in comparison, a much smaller range was observed for the genotype mean yields across environments.

Analysis of variance components for yield indicated the presence of a large and significant genotype x environment (g x e) component. It was noted also that the environmental component was considerably larger than the genotypic component, suggesting that it is possible to improve by manipulation agronomically-controllable environmental variables; and also that genotypes used tended to have rather narrow genetic bases for yields. Further partition of g x e indicated significant variance components of genotype x line (g x l) and genotype x line x site (g x l x s), whereas g x s interaction was virtually unimportant.

Hybridization Program

On the basis of present studies, hybrids have been synthesized to increase genetic variability for further selection to improve yield or yield stability. The F_2 seeds for these hybrids will be used for pedigree selection and will form a composite bulk population that interested cooperators can grow in various regions of Malaysia.

Genetic and Environmental Control of Soybean Seed Protein

The protein content of cultivars conducted in the first evaluation trial was analyzed. Significant variation was found in seed protein, which ranged from 16.8 to 39.7 percent. The effects of *Rhizobium* strains on seed protein content are unknown because seed samples from this study have not been analyzed. However, as far as grain yield and nodule number are concerned, soybean seed inoculated with *Rhizobium* performed better than the noninoculated control. Out of the four strains of *Rhizobium* studied, one appeared to be superior.

UPM BREEDING, QUANTITATIVE GENETICS, AND EVALUATION PROGRAM

The UPM role in the Joint Malaysian Soybean Breeding Project is to conduct comprehensive research on breeding, quantitative genetics, and the evaluation of materials bred by the partners of the project at various locations in Malaysia. The materials tested will eventually be released as cultivars suitable for local conditions.

Performance of Segregating Lines

A trial using 52 lines obtained from AVRDC was carried out (15). Correlation coefficients and path coefficient analysis of these lines are shown in Tables 6 and 7. The characters studied include plant height, branches per plant, nodes per plant, pods per plant, seeds per plant, seed weight, and flowering date.

CONCLUSION

The Joint Malaysian Soybean Breeding Project is a unique undertaking in the history of agricultural research in Malaysia in that it brings together five institutions. It is hoped that the project will serve as a model for other cooperative projects in the future. Such coordinated programs not only increase the effectiveness of reaching a given target but also serve as a means of increasing communication and understanding among the scientists of the various institutions. Above all, they promote cooperation between universities and research institutions.

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Table 6. Simple Correlation Coefficients between Characters for the 52 Lines of Soybeans, 1979

Character	Plant height	Branches/ plant	Nodes/ plant	Pods/ plant	Seeds/ plant	Seed weight	Pods/ node	Flowering date
Yield	0.33*	0.44**	0.55**	0.66**	0.65**	-0.18	0.08	0.4**
Plant height		0.33*	0.64**	0.45**	0.39**	-0.29*	-0.56**	0.16
Branches/ plant			0.77**	0.69**	0.71**	-0.59**	-0.37	0.68**
Nodes/ plant				0.9**	0.88**	-0.61**	-0.47**	0.57**
Pods/ plant					0.97**	-0.55**	-0.07	0.57**
Seeds/ plant						-0.63**	-0.05	0.63**
Seed weight							-0.31	-0.64**
Pods/ node								-0.17

Source: Yap and Tan (15).
*P = 0.05.
**P = 0.01.

Table 7. Direct and Indirect Effects of Agronomic Characters on Seed Yield Based on the Path Coefficient Analysis, 1979

Indirect effects via	Plant height	Branches/ plant	Nodes/ plant	Pods/ plant	Seeds/ plant	Seed weight	Pods/ node	Flowering date
Plant height	(0.28)	0.09	0.18	0.13	0.11	-0.08	-0.16	0.05
Branches/ plant	0.04	(0.12)	0.09	0.08	0.09	-0.07	-0.04	0.08
Nodes/ plant	-0.19	-0.23	(-0.3)	-0.27	-0.26	0.18	0.14	-0.17
Pods/ plant	0.01	0.02	0.03	(0.03)	0.03	-0.02	0	0.02
Seeds/ plant	0.33	0.6	0.75	0.83	(0.85)	-0.53	-0.05	0.54
Seed weight	-0.12	-0.25	-0.26	-0.23	-0.27	(0.42)	0.13	-0.27
Pods/ plant	-0.05	-0.03	-0.04	-0.01	0.01	0.03	(0.09)	-0.02
Flowering date	0.03	0.12	0.1	0.1	-0.11	-0.11	-0.03	(0.17)
Total correlation	0.33	0.44	0.55	0.66	0.65	-0.18	0.08	0.4

Source: Yap and Tan (15).
Note: Values in brackets are direct effects, whereas other values in the same column are indirect effects via the characters concerned.

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Nepal

RAJMAN P. CHAUDHARY

Nepal is a landlocked mountain country located between India and China at between 27° and 30° north latitude, with an area of approximately 2.4 million hectares. There are four agroclimatic regions: terai, inner terai, mid-hills, and high hills.

The annual rainfall ranges between 2,000 mm in the eastern part of the country and less than 1,000 mm in the western part. Of the total rainfall, 85 percent comes during the monsoon periods from June to November. The temperature varies from subtropical heat in the terai (up to 46° C in June) to extreme cold in the perennially snowcapped mountains of the Himalayas. Temperatures vary even within a short distance in the hills, depending upon the altitude and the direction and degree of slope.

Soybeans are an ancient crop in Nepal. The, were grown only in the mid-hills at altitudes of from 915 to 1525 m (3,000 to 5,000 feet) until a few years ago, but the crop is gaining popularity in other parts of the country day by day. Although soybeans are still a minor part of the country's total agriculture, this summer legume crop plays a very important role in human and animal nutrition, soil fertility, and the cropping system of Nepal. Soybeans are consumed mainly by roasting the dried seeds for the daily tiffin, but they are also used as a green vegetable. They can be enjoyed as a snack by removing the seed coats of parched soybean seeds, splitting the cotyledons and mixing them with garlic, hot pepper, salt, and mustard oil. Also, sprouted beans are used to make vegetable soup.

An exact figure for the total area of soybeans in Nepal is not currently available, but it is estimated to be at least 70,000 ha. According to a survey by agricultural statisticians, the area under soybeans in 1972 was 18,040 ha, with 10,824 metric tons produced for an average yield of 600 kg per ha. Statistical surveys have not been done since 1977, but it was estimated then that the area in soybeans was 70,000 ha with a production of 45,500 metric tons and an average yield, therefore, of at least 650 kg per ha.

Since soybeans are not usually a sole crop, land is not prepared to be planted in soybeans alone. Soybeans are planted mixed with such crops as corn (maize), pigeon peas, and paddy rice. Farmers use paired rows of corn 50 cm apart with soybean hills that are 15 cm apart in between. The seeding rate is approximately 100 kg per ha. Soybeans are planted in May in the hills and in June and July in the terai. They are planted on the hill terraces and on rice field bunds after paddy transplanting. Those that are grown on paddy bunds are late-maturing types. Soybeans are harvested in September and October.

On government farms and agriculture stations, land is prepared by plowing and then harrowing twice. Planting, which is done by dibbling soybeans as a sole crop at the rate of 60 kg seeds per ha, begins by the middle of May or middle of June. Crops are harvested by the end of September or the middle of October.

Most farmers use indigenous germ plasm on small holdings. However, a few progressive farmers have been convinced to grow introduced cultivars such as Hardee in the terai and Hill in the hills. These two cultivars are also being used on government farms and stations.

Fertilizer is not generally used for soybeans in farmers' fields. However, 50:50:30 NPK is being used on government farms and stations in the form of ammonium sulphate (20 percent N), urea (46 percent N), complex fertilizers (20:20:0 NPK), and muriate of potash (60 percent K). All kinds of fertilizers are used as a basal dose. There is no response to nitrogen under Kathmandu conditions, and, so far, no work on nitrogen response has been done outside the Kathmandu Valley.

Rhizobium inoculation studies on soybeans were done at three locations: Khumal Tar

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(Kathmandu), Kakahi (nearly 2440 m (8,000 feet) above sea level), and Pakhribas (1764 m (5,800 feet) above sea level) in 1975, 1976, and 1977. Indigenous *Rhizobia* were used for the studies, which all indicate that there were statistically significant increases in soybean yield and nitrogen response with *Rhizobium*. The response of indigenous *Rhizobium* was not statistically significant. *Rhizobium* cultivars were collected from the United States, Australia, the United Kingdom, Sweden, and India. Local *Rhizobium* strains were collected from different parts of the country.

Following are the major soybean diseases:

1. Cercosporella leaf spot—*Cercosporella* sp.—a disease new to the world, observed in Nepal only;
2. Frogeye leaf spot—*Cercospora sojina*;
3. Bacterial pustule—*Xanthomonas campestris* pv. *phaseoli*;
4. Anthracnose—*Colletotrichum dematium* var. *truncata;*
5. Soybean mosaic—soybean mosaic virus; and
6. Yellow-mosaic—yellow mosaic virus.

The major insect pests found in Nepal are:

1. Hairy caterpillar—*Diacrisia multiguttata* and *Spilarctia casignata*;
2. Aphid—*Aphis glycine* and *A. gossypii*;
3. Chinch bug—*Chauliops fallax*;
4. Tobacco caterpillar—*Spodoptera litura*; and
5. Stinkbug—*Nazara viridula*.

Minor insects found in Nepal are:

1. Epilachna beetle—*Epilachna vigintioetopunctata*;
2. Flea beetle—*Phyllotreta sinnuata*;
3. *Platyptilia histrix*;
4. *Alcinodus* sp.;
5. *Apion* sp.; and
6. White fly—*Bemisia tabaci*.

Vertebrate pests found in Nepal are:

1. *Bandicota Bengalensis*;
2. *Bandicota Indica*; and
3. Grey slug.

Nepal's Grain Legume Improvement Programme (GLIP) does not have a seed production program. However, a few government farms and stations have started seed production programs for the imported cultivars, Hardee and Hill. The Agriculture Inputs Corporation (AIC) in Nepal supplies seeds, fertilizers, insecticides, fungicides, agricultural tools, etc. to farmers. In addition, soybean seeds are distributed to farmers directly by GLIP in the form of minikits and production demonstration packets.

The average yield of soybeans from farmers' fields has been found to be 0.65 metric tons per ha and, from government farms and stations, 1.5 to 2 metric tons per ha. Soybean production costs have not yet been determined by GLIP.

The following principal factors limit soybean production in Nepal: (1) low-yielding indigenous cultivars, (2) cultivar susceptibility to diseases and insects, (3) market problems, (4) food habits, and (5) lack of government support for soybean production as a separate program.

ORGANIZATION

GLIP has been operating under the Ministry of Food and Agriculture. There is not yet a separate program for soybeans. Personnel working on soybeans are required to work with other legumes and pulses as well as other crops. We have very good coordination with international agencies such as INTSOY, AVRDC, and the University of Queensland, Australia.

We have the following technical manpower; M.P. Bharati, M.Sc.Ag. (Australia); R.P. Chaudhary, M.S. (U.S.A.); J.J. Manandhar, M.S. (U.S.A.); Mrs. S.L. Maske, M.Sc. (T.U.); S.L. Joshi, B.Sc.Ag. (India); and R.K. Neupane, B.Sc.Ag. (India).

The personnel and level of training required for the soybean development program for the next ten years are: one agronomist, Ph.D.; one breeder, Ph.D.; one physiologist, Ph.D.; one pathologist, M.S. or Ph.D.; one entomologist, M.S. or Ph.D.; one microbiologist, M.S. or Ph.D.; one production agronomist, M.S.; one food technologist, M.S.; one nutritionist, M.S.; one agro-economist, M.S. or Ph.D.; one agricultural engineer, M.S.; three extension workers, with three to six months' training in soybeans; and ten junior technicians, with training in soybean production.

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Pakistan

A. RAHMAN KHAN AND A. QAYYUM

Pakistan is deficient in the production of edible oil. National edible oil consumption, increasing at an average rate of 50,000 tons annually, reached a level of 713,000 tons in 1980-81. With an increased per capita demand for vegetable ghee and a population growth of more than 3 percent per annum, the demand for crude vegetable oil will rise to 892,000 tons by 1984-85 (Table 1). The need to import 420,000 tons in 1979-80 resulted in an estimated foreign exchange expenditure of 2,715 million rupees. Therefore, a substantial increase in domestic production is necessary to curtail foreign imports.

The principal indigenous oilseed crops that contribute to the production of edible oil include cottonseed, followed by rape and mustard seed. Rape and mustard will most likely make equal contributions to about 50 percent of the edible oil by 1982-83. All the groundnut produced is consumed as roasted nuts or as confections. The entire seasame yield is also used in confections.

Three new crops have been added to the list of oilseed crops grown here. These are sunflowers, soybeans, and safflowers, all of which were introduced and tested during the early 1960s. Their commercial production was established about a decade ago.

Soybeans have been the most successfully grown of the newly established crops, and growers have shown more enthusiasm for this crop than the others. Attempts at developing commercial acreage have been most successful in the high-rainfall northern areas and in the irrigated central and southern areas of the country.

Interest in commercial development has followed the good performance of some introduced cultivars in test plots. Cultivars with varying lengths of maturity have been identified for specific areas. Cultivars like Bragg, Lee-68, and Williams are well adapted, with a yield potential of 2,072 to 4,321 kg per ha on experimental plots in the northern areas. Bossier has recently been recommended for commercial production in southern areas, and Bragg, Hampton 266-A, and Improved Pelican are earmarked for general production in central areas (Figure 1).

With increased production, problems connected with the disposal of soybean meal after oil extraction may arise. However, the recent utilization of soybean meal as poultry and livestock feed by various private concerns promises to provide a dependable outlet for the disposal of meal. The growing number of cattle feed plants will mean an increased demand for soybean meal.

The other basic material for the manufacture of livestock feed is molasses, which is already available in substantial quantities. There are 34 sugar mills already in production, so the manufacture and export of cattle feed would not only solve the soybean meal disposal problem but also aid the operational economics of the solvent extraction plants.

PRODUCTION TECHNOLOGY

Both the area and the production of soybeans have been increasing since commercial production began over a decade ago. Table 2 shows the increases from 1975-76 to 1979-80.

CULTURAL PRACTICES

In a calendar year there are three crops: a spring crop planted in February and harvested in May or June, a kharif crop planted with the beginning of the monsoon rains and harvested in October, and an autumn crop planted in late August or early September and harvested in November. The seeding rate is from 75 to 100 kg per ha,

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depending upon the cultivar used, planting time, and the fertility level. Seeds are sown from 4 to 5 cm deep in rows 45 to 60 cm apart, with either a hand drill or a cottonseed drill that equally distributes seeds 6 to 10 cm apart. After pods have dried in the sun for seven to ten days, threshing is done by beating the pods by hand or running over the harvested pods with a tractor. Seeds are stored at a moisture content below 12 percent.

CROPPING PATTERNS

Soybeans are mostly grown in rotation with wheat both in irrigated and in rainfed areas. In irrigated and high-rainfall areas, the soybean crop fits in satisfactorily with wheat in the cropping system. Wheat yields are slightly higher when wheat follows soybeans.

Cultivars used in the commercial production of soybeans have been introduced. No indigenous germplasm resources are available. Details about the adapted cultivars are given in Table 3.

FERTILIZER

The use of fertilizer on soybean crops in Pakistan is negligible, though it is well established that this crop responds favorably to fertilizer application. In irrigated areas, a 50:57 N:P kg per ha and, in the barani areas, a 22:57 N:P kg per ha is recommended. The effects of fertilizer and inoculum on soybean crops are given in Table 4.

The most common types of fertilizer available are DAP and urea, with a government-fixed price of $10 (U.S.A.) and $9.30 (U.S.A.) per bag of 50 kg, respectively. Most of the fertilizer used is applied in one dose during the planting operation.

RHIZOBIUM INOCULUM

Rhizobium inoculum is not widely used in commercial production but rather for experimental and demonstration purposes. Commercial *Rhizobium* inoculum is imported (Nitragin) for research use only. It is mixed with the seed at the time of sowing. Little or no native *Rhizobium* inoculum is used.

The effects of different types of inoculum on nodulation and yield of the soybean cultivar Suehsine are given in Table 5.

MECHANIZATION

Soybeans are cultivated on small scattered acreages. Various field operations, such as planting, weeding, harvesting, and threshing, are done manually. Some prototypes of simple agricultural implements have been developed for small- and medium-scale growers.

Top priority is being given to the development of the thresher. PARC, in collaboration with its IRRI-PAK Machinery Division, has developed a prototype of multipurpose thresher that threshes soybeans rapidly with very little damage to the grain. However, since it is still in the final stage of testing, the mechanization of soybean cultivation in Pakistan is not yet a reality.

IRRIGATION

Soybeans are successfully grown in barani areas of the northern part of Pakistan, where there are 50 to 60 cm of rainfall during the growing season. They are a substitute for maize and are followed by wheat planted in the winter. Soybeans are planted in flat beds in barani areas rather than in raised beds as in the rainfed areas.

Moisture stress at flowering and pod development stages results in a low yield. For a successful harvest, irrigation is required after 15 or 20 days in the central and southern areas. About 75 acre-cm of water are required in Sind.

PLANT PROTECTION

No serious insect pest or disease problems have been reported so far in Pakistan, except for damage by field crickets, white ants, jassids, and white flies, and minor trouble with postemergence damping-off and root rot. Nevertheless, some cultivars are susceptible to yellow mosaic virus, which causes significant yield losses. The cultivar Williams is fairly resistant to this virus. Spraying with recommended doses of insecticides is done when needed. Two to three hoeings, either by hand or with rotary hoes, are required in each stage of growth for weed control.

Table 1. Edible Oil Requirements of Pakistan, 1979-85

Year	Anticipated production (1,000 tons)	Anticipated consumption (1,000 tons)	Anticipated deficit (1,000 tons)
1979-80	247[a]	667[a]	420[a]
1980-81	332	713	381
1981-82	370	758	388
1982-83	420	804	384
1983-84	471	850	379
1984-85	520	892	372

[a]Estimated data.
Source: Report on Oilseed Production Strategy for Pakistan, 1977.

Table 2. Area and Production of Soybeans in Pakistan, 1974-80

Year	Area (ha)	Production (tons)
1974-75	957	443
1975-76	833	403
1976-77	1,662	615
1977-78	3,049	1,290
1978-79	3,437	1,755
1979-80	4,000[a]	2,052[a]

[a]Estimated data.
Source: Crop Statistics of Pakistan Food and Agriculture Division, 1980.

Table 3. Origins and Salient Features of Adapted Soybean Cultivars in Pakistan

Cultivar	Origin	Salient features
Improved Pelican	U.S.A.	Tall cultivar; late in maturity; yield potential = 1350-3500 kg/ha; recommended for central areas.
Bragg	U.S.A.	Late in maturity, extensively grown; yield potential = 2070-4320 kg/ha.
Lee 68	U.S.A.	Late in maturity; yield potential = 2300-4300 kg/ha.
Bossier	U.S.A.	Late in maturity; yield potential = 2000-4000 kg/ha; recommended for southern areas.
Forrest	U.S.A.	Medium in maturity; yield potential = 1400-3000 kg/ha.
Columbus	U.S.A.	Medium in maturity; yield potential = 2000-3000 kg/ha.
Williams	U.S.A.	Early in maturity; yield potential = 2500-4000 kg/ha; very popular in foothill areas of northern Pakistan.

Source: Annual reports of Cooperative Research on Oilseed Crops, Pakistan Agricultural Research Council, Islamabad, 1977-78 and 1978-79.

SEED PRODUCTION PROGRAM

No seed production program was developed in Pakistan until very recently. A project for the rapid development of oilseed crops was started under the FAO in 1980, and under this project 175 kg of quality seed, the cultivar Williams, was imported for seed multiplication last year. Fifteen tons more are expected in 1981. This seed will also be used for multiplication by the Punjab Seed Corporation, provincial agricultural departments, and progressive growers. Quality seed is usually supplied by PARC to the growers in crop-specified areas. Provincial agricultural departments and the Ghee Corporation of Pakistan supply seed to growers in different soybean-growing areas.

YIELD

The farmer's average yield of 511 kg per ha and the highest yield potential of 4,321 kg per ha are presented in Table 6.

The highest yield, 4,321 kg per ha for Lee 68, was obtained in the northern area. In a cultivar evaluation test in 1974 (Table 7), Bragg also yielded 4,145 kg per ha but did not differ from the Lee 68 yield at the 5 percent level of significance. Williams did yield significantly lower than Lee 68, but its early maturity and comparative resistance to yellow mosaic virus favor its commercial cultivation. Similarly, Williams yielded 1,120 kg per ha, which was significantly lower than Bragg, 1,549 kg per ha, at the 5 percent level of significanc (Table 8). However, the maturity difference between Bragg and Williams came to 13 days. The time factor is very important when soybeans are to be followed by wheat.

COST OF PRODUCTION

The comparative economics of soybean, maize, and sunflower cultivation under irrigated conditions is presented in Table 9. The net return from soybeans is highest, followed by maize and sunflowers. The sunflower return is uneconomical because the market price is not attractive. It should be pointed out, however, that the government is expected to increase the market price for sunflower seeds by $1.50 (U.S.A.) per 37.5 kg. This change would make sunflower cultivation profitable.

CONSTRAINTS

The major constraints to soybean production in Pakistan are (1) inadequate seedbed preparation by farmers, (2) inferior seed, (3) inadequate use of inoculum and/or fertilizer, (4) unavailability of sources of credit for the purchase of inputs, (5) lack of an attractive price for the produce, and (6) unavailability to farmers of a soybean thresher.

ORGANIZATIONS

The soybean research and development program is associated with programs for other oilseed crops. The Pakistan Agricultural Research Council coordinates the activities with various concerned agencies, including (1) the Pakistan Agricultural Research Council, at the national level, under the Agricultural Research Division of the Ministry of Food and Agriculture; (2) agricultural departments under the Provincial Ministry of Agriculture; and (3) the Ghee Corporation of Pakistan, which is under the Ministry of Industries.

RESEARCH FACILITIES

The following facilities are available for soybean research and developmental activities as part of the greater oilseed crops program in Pakistan: (1) laboratories to evaluate germplasm and improve available production technology; (2) technical staff; (3) state farms and other resources to multiply quality seeds; (4) administration of infrastructure and overall coordination of the projects; (5) agricultural extension workers in soybean-growing areas; (6) facilities for extraction of edible oil and disposal of meal and cake; (7) basic equipment and fertilizer, insecticides, and fungicides.

Locally-trained staff is conducting research and development. Only two members were sent abroad for a brief training period at the University of Illinois at Urbana-Champaign. Table 10 shows anticipated needs in manpower for the coming years.

DISCUSSION

M.A. Khaleque: It appears that a soybean cultivar called Improved Pelican is widely grown in Pakistan. It was also grown in Bangladesh and found to be susceptible to yellow mosaic. It gave high yields and was late to mature. How does this cultivar perform in Pakistan?

A. *Rahman Khan:* Improved Pelican is still being grown in irrigated southern areas of Pakistan. Its yields are almost equivalent to other higher yielding cultivars, but its maturity range is between 125 and 135 days. Hence, it is late to mature. It is also susceptible to yellow mosaic virus.

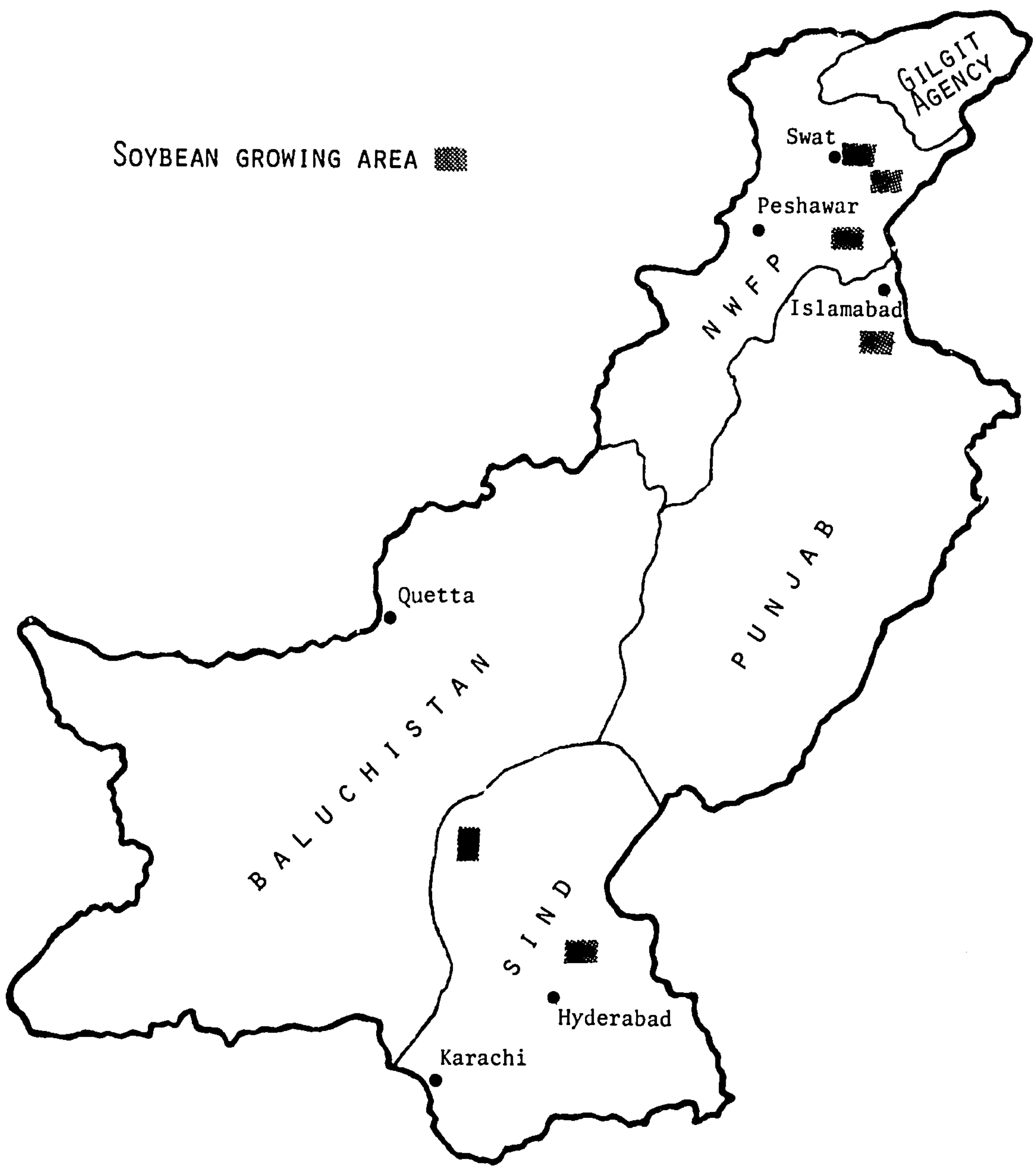

Figure 1. Map of Pakistan.

Table 4. Effect of Fertilizer Application on Soybean Cultivar Woodworth under Barani Conditions at NARC, Islamabad, 1979-80

Number	Treatment (kg/ha) N	P	K	Grain yield (kg/ha)	100-seed weight (gm)
1. F0	0	0	0	715	12
2. F1	20	0	0	754	13
3. F2	0	50	0	1.146	14
4. F3	20	50	0	925	14
5. F4	10	50	50	986	13
LSD at 5%				184	NS
LSD at 1%				258	

Table 5. Effect of Different Types of Inoculum on Nodulation and Yield of Soybean Cultivar Suehsine at Tandojam, 1978-79

Treatment	Nodules/plant (average)	Pods/plant (average)	Yield (kg/ha)
Control	1.8	50.7	1,033
Nitragin powder	15.2	49.3	1,067
Nitragin granular	13.4	47.5	877
Urbana	9.9	51.1	1,129
Granular	5.0	50.8	1,067
+ 11 kg N/ha	1.7	56.6	741
Molynoctin L.	2.7	51.6	929
Mean	7.13	51.1	977.57
LSD 5%	5.33		
LSD 1%	7.30	NS	NS

Table 6. Yield of Soybeans under Various Farm Conditions in Pakistan, 1974

Farmer's average yield	State farms	Best yield obtained	Yield potential
	kg/ha		
511	2,072-4,321	4,321	4,321

Source: The Present Status of Research on Oilseeds in NWFP. Proceedings of First National Oilseed Seminar, 1975.

Table 7. Soybean Yield Test at Swat, Pakistan, 1974

Cultivar	Yield (kg/ha)
Lee 68	4,321
Davis	4,309
Bragg	4,145
Bonus	4,028
Williams	3,982
Semmes	3,914
Clark 63	3,841
Hill	4,230
Forrest	3,560
Bossier	3,048
Tracy	2,905
Improved Pelican	2,072
LSD 5%	277

Source: Proceedings of First National Oilseeds Seminar, 1975.

Table 8. Cultivar Trial on Soybeans at NARC, Islamabad, Pakistan, 1977

Cultivar	Plants per plot	Plant height at maturity (cm)	Pods per plant	Shattering (%)	Lodging (%)	Maturity (days)	Yield (kg/ha)
Cobb	261	93	18	2.5	5	120	613
Semmes	253	87	25	...	...	105	873
Mitchel	245	69	18	...	...	92	947
Bossier	253	100	20	3.75	4	120	1,096
Essex	257	58	17	...	...	92	869
Bragg	291	102	25	...	3	105	1,549
Williams	276	72	17	...	3	92	1,120
Columbus	233	69	16	...	...	92	968
B-1	243	102	15	1.75	1	120	1,046
Ransom	262	86	22	0.75	1	120	952
Kahala	205	70	16	20.25	18.7	92	672
Clark 63	205	67	15	4.6	...	92	966
Davis	267	94	21	1.25	3	105	963
Calland	242	71	15	6.00	5	92	589
Rillite	245	86	23	2.5	...	105	652
Forrest	241	86	20	...	...	105	969
LSD	5%						405
LSD	1%						540

Source: Annual report of Cooperative Research on Oilseed Crops, PARC, Islamabad, 1977-78.

Table 9. Cost of Production and Net Return from Soybean and Competing Crops, Like Maize and Sunflower, under Irrigated Conditions in Pakistan

Crop	Cost of production		Net return	
	Excluding land rent	Including land rent	Excluding land rent	Including land rent
	U.S.A. $/ha			
Soybean	250	287	245	208
Maize	331	383	167	105
Sunflower[a]	195	232	36	-1

[a]Average of irrigated and nonirrigated conditions.

Source: Cost of Production of Major Crops, under Irrigated and Nonirrigated (Barani) Conditions. Government of Pakistan, Planning and Development Division, Agriculture and Food Section, June, 1979.

Table 10. Manpower and Level of Training needed for Soybean Development Program for the Coming Ten Years

Discipline	Ph.D.	M.Sc.	Study tours
Agronomy	1	1	5
Plant breeding	...	1	3
Entomology	...	1	3
Plant pathology	...	.	3
Soybean technology	...	1	3

The Philippines

FLORENCO C. QUEBRAL

The domestic supply of soybeans has never been sufficient to meet national demands for food, feed, and industrial uses. Total domestic soybean production in 1978 was reported to be 7,099 metric tons. Approximately 176,000 metric tons of soybeans, costing $30.8 million, were imported.

To boost domestic production, the government has launched projects like Masaganang Maisan, the white corn and feed grains program, and the National Soybean Development Program. The former is intended to increase the production of soybeans for feed purposes; the latter, for food and nutrition.

CULTIVAR IMPROVEMENT

Soybean cultivar improvement is carried out in the Bureau of Plant Industry and the University of the Philippines at Los Baños. The work focuses on introduction and acclimatization, as well as selection and hybridization of superior cultivars and strains. More than 1,000 plant introductions from the U.S.A. (including Hawaii), China, Japan, Java, and India have been screened for yield, plant type, pest resistance, and drought tolerance.

Recommended Seed Board cultivars and promising soybean cultivars for the Philippines are listed in Table 1.

One important constraint to production is the combination of rapid loss of seed viability and the difficulty of getting a good stand in the field. Seed viability is completely lost after five months of storage.

PLANTING

The best time to plant soybeans in the Philippines is in the latter part of May or in June for the wet season crop and October for the dry season crop. Soybeans may be planted the first week of November if there is enough moisture or supplemental irrigation. However, planting beyond October has drawbacks, such as hastening flowering so that it occurs before the plants have reached optimum vegetative and reproductive growth, and a limited supply of soil moisture, especially in areas where there are no irrigation facilities.

The row spacing and orientation influence the amount of light that can be utilized by plants. Studies have shown that planting soybeans in February, March, May, and June gives higher yields than planting in August and September. During the months with shorter day lengths, plant height, seed weight, number of pods, nodule count, leaf area index, and pod straw are all reduced when soybeans are planted at wider row spacings.

Planting time, seeding rate, and population density are dependent on the requirements for the recommended Philippines Seed Board cultivars (Table 2).

INOCULATION AND FERTILIZATION

In the Philippines, limited studies have been done on the selection of effective *Rhizobium* strains and their use in legume production.

At present the *Rhizobium* bacterial strain Brazil 114 is used to inoculate soybean seeds.

Rate of fertilization is affected by season. During the dry season inoculation and fertilizer application, using three bags of ammonium phosphate (24 kg N and 30 kg P_2O), are recommended. In the wet season, inoculation with or without phosphate fertilizer is suggested.

The fertilizers are applied evenly in a narrow, continuous band at the bottom of the furrow and covered with 2 or 3 cm of fine soil. The seeds are then drilled above the covered fertilizer.

PESTS AND DISEASES

The pests that attack soybeans in the Philippines are numerous, but those that

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Table 1. *Recommended Seed Board and Promising Soybean Cultivars for the Philippines*

Cultivar	Parental stock	Yield (t/ha)	Seasonal adaptability (planting)	Maturity (days)[a] DS	WS	Developing agency[b]	Special characteristics
RECOMMENDED							
L-114	C363 x Sankuo	1.5	October	110-115	...	BPI	Better seed viability and tolerance to a certain strain of soybean rust; recommended for processing; 18.7% oil and 36- and 36-43% protein.
CES-434	Bilomi x EG	2	May, June, October, and February	110-115	...	UPLB	Very susceptible to bacterial pustule, nonshattering.
Clark-63	...	2	May, June, October, and February	80-90	95	Introduction	Resistant to bacterial pustule, nonshattering, earliness. Susceptible to rust.
Tk-5	...	2	May, June, October, and February	80-85	95	Introduction	Resistant to a strain of rust and shattering, susceptible to bacterial pustules.
UPLB-Sy2	Tk-5 x Clark-63	2	May, June, October	86	96	UPLB	Resistant to bacterial pustule and to a strain of rust.
PROMISING							
Vesoy 1	C399 x Malobini	6 (green) 1.2 (dry)	...	70-75(Green) 90-95(dry)	...	BPI	Fairly tolerant to bacterial pustule. Recommended for green pod vegetables, 14-18% oil, 44-46% protein.

(Table cont'd)

[a]DS = dry season; WS = wet season.
[b]BPI = Bureau of Plant Industry; UPLB = University of the Philippines at Los Baños.

Table 1. Cont'd

Cultivar	Parental stock	Yield (t/ha)	Seasonal adaptability (planting)	Maturity (days)[a]		Developing agency[b]	Special characteristics
				DS	WS		
Vesoy 2 and Vesoy 3	Hahto x Rokusum	7.0 (green) 1.5 (dry)	...	195	...	BPI	Susceptible to soybean rust and fairly tolerant to bacterial pustule. Recommended for green vegetables, 16-17% oil, 45-48% protein.
BPI-12A (VLCS-12A)	L-114 x SRF 307	2.8	...	100-105	...	BPI	Resistant to shattering and to certain strains of rust and bacterial pustule. Recommended for processing, 19-24% oil, 38-44% protein.
BPI-12-A-1	L-114 x SRF 307	2.7	...	105-115	...	BPI	Less affected by climatic conditions. Stable yield from different regions. Suitable for Mindanao planting. Slightly shattering and suitable for processing, 20-24% oil and 39-44% protein.
PI 230970	...	...	...	...	...	Introduction	Resistant to rust.
PI 230971	...	...	...	...	...	Introduction	Resistant to rust.

[a]DS = dry season; WS = wet season.
[b]BPI = Bureau of Plant Industry; UPLB = University of the Philippines at Los Baños.

merit attention are (1) weeds such as *Rottboellia exaltata*, *Cyperus rotundus*, and *Ipomea triloba*; (2) diseases such as rust, bacterial pustule, damping-off, and seed decay; and (3) insects such as beanflies, cutworms, corn earworms, aphids, leaf folders, and pod borers.

COSTS AND RETURNS

Hired labor accounts for the largest expense (276.53 pesos or 24 percent) per ha incurred in soybean production. Chemical inputs add 11 percent of the total expense, or 133.02 pesos.

Table 2. Recommended Seeding Rates and Planting Dates for Soybean Cultivars in The Philippines

		Seeding rate		Population desired	
Cultivar	Planting time	kg/ha	Seeds/m[a]	Plants/row[b]	Total (in 1,000)
CES-434	October	41-44	22	18	300
	May-June	30-32	15	12	200
L-114	October	41-44	22	18	300
	May-June	30-32	15	22	200
Clark - 63	May-June	41-44	22	18	300
	Late January or early February	50-52	28	24	400
TK - 5	May-June	41-44	22	18	300
	Late January or early February	50-52	28	24	400
UPLB Sy-2	May-June	41-44	22	18	300
	October	50-52	20	24	400

[a]Based on 85% germination.
[b]Based on 60-cm spacing between rows.

INTENSIVE CROPPING

Soybeans are a good crop for multiple cropping. In lowland rice fields, soybeans are grown as a crop preceeding or immediately following rice. In areas where upland rice or corn is the main crop, soybeans are grown as a rotation crop or intercrop. When intercropped with corn, soybeans are planted in rows between rows of corn with 40 seeds per m^2. Soybeans are also intercropped with sugarcane and coconut.

UTILIZATION

Government research agencies and educational institutions have studied the utilization of soybeans. Researchers at the University of the Philippines at Los Baños have produced bottled soymilk (Philsoy) using the hot water grind technique they developed with the cooperation of a visiting professor from Cornell University, U.S.A. Fermented soybean products, such as soy sauce, soy cheese (tokwa), soy paste (miso), soy curds (tahuri), and canned salted beans (tausi) are the most common soybean products used as ingredients in traditional Filipino dishes. A cheese-like product served with sugar syrup (taho) is sold by ambulant pedlers in urban centers.

For noncash expenses, the three major items are interest on investment, labor (including operator, family, and exchange labor), and landlord share, all of which account for 37 percent (429.24 pesos) of the whole amount. Noncash expenses are higher than cash expenses by 8 percent. Total expenditures amount to 1,162 pesos, or about 64 percent of the total income (Table 3).

Total income realized amounts to 1,828 pesos, making a net profit of 665.34 pesos, or 0.79 pesos per kilo produced.

MARKETING

Farmers usually sell the bulk of their produce and keep the remainder for home consumption or for seeds. The produce is usually sold at the farm, farmstead, roadside, or buyer's place of business. Handling, transportation, and container costs are shouldered by the producers.

Farmers usually sell their produce to processors, consumers, agents, assembler-wholesalers, retailers, or wholesaler-retailers.

To prevent the depression of prices to unprofitable levels during peak

Table 3. Soybeans: Estimated Costs and Return per Hectare, Southern Mindanao, the Philippines, 1976

Item	Amount (pesos)	Percentage of total
Income		
Cash	1,515.31	83
Noncash[a]	312.35	17
Total income[b]	1,827.66	100
Expenses		
Cash	...	...
Seed	17.00	2
Fertilizer	20.91	2
Chemicals	133.02	11
Hired labor	276.53	24
Rent (Equipment, ani-⁻al tractor)	37.28	3
Container	2.00	c
Delivery	5.69	c
Food (hired, exchanged, labor)	15.00	1
Interest on loan	5.39	c
Land payment	18.26	2
Tax	7.87	1
Subtotal	538.95	46
Noncash		
Seed	53.28	5
Labor (operating, farm exchange)	134.72	12
Interest on investment	166.20	14
Depreciation	13.39	1
Landlord	128.32	11
Harvester, thresher	120.63	10
Payment for seed in kind	66 83	1
Subtotal	623.37	54
Total expenses	1,162.32	100
Net profit	665.34	...
Net profit kilo	0.79	...

Note: Based on one cropping only.
[a]Includes landlord, harvester, thresher, seed, home use unsold, and payment in kind of seed.
[b]Based on approximately 842.24 kilos at 2.17 pesos per kilo.
[c]Less than 1 percent.

production periods, the National Grains Authority (NGA) gives a price support of 3.55 pesos per kilo (LOI 1046) to assure a fair return on investment.

Both wholesale and retail soybean prices increased from 1969 to 1976. The only decline was in 1975, when they went down by 4 percent, from 126.82 pesos to 121.89 pesos (Table 4). In 1976 there was a great difference between wholesale and retail prices, with consumers paying 1.97 pesos per kilo more than wholesalers.

MARKETING PROGRAM

The NGA has entered into agreements with various financial institutions that extend capital loans to farmers. Arrangements have been drawn up whereby farmers deliver produce to the NGA as payment on loans. Upon receipt of such produce, the NGA notifies the lending institution of the amount delivered, and the lending institution credits the farmer's account. Procurement in kind (PINK) may also be arranged. Farmers deliver stocks directly to lending institutions that have bonded warehousing facilities, and the lending institutions in turn sell the stocks to the NGA and credit the proceeds to the farmers' accounts.

The NGA requires a certain quality for direct procurement and procurement in kind. Soybeans must have less than 13 percent moisture content, at least 98 percent purity, less than 3 percent total damaged kernels, and less than 20 percent splits. They may be yellow, green, brown, or black cultivars and they must be free from infestation and unpleasant odor.

Table 4. Soybeans: Wholesale and Retail Prices in Pesos, the Philippines, 1967-1979

Year	Wholesale (per 50 kg)	Retail (per kilo)
1967	...	...
1968	...	...
1969	44.54	1.09
1970	55.02	1.36
1971	69.09	1.44
1972	74.68	1.76
1973	110.13	3.14
1974	126.82	3.64
1975	121.89	3.76
1976	133.31	4.64
1977	219.56	...
1978	218.50	...
1979	244.50	...

AREAS THAT NEED ATTENTION

The following areas require further attention from scientists and specialists:

1. Hybridization and screening of germplasm for resistance to beanflies, weevils, nematodes, and viruses; to leaf, stem, and root diseases; and to stress conditions such as drought, water logging, shading, and acid soils.
2. Screening of germplasm for day neutrality, higher amino acid content, and higher N-fixing capability.
3. Refinement of techniques in the prevention of a high percentage of flower and pod abortion, the production of quality seeds, water management, seed and inoculation of appropriate *Rhizobium* strains, seed viability and storage, and control of pests and diseases.
4. Food processing and utilization for the development of appropriate food from soybeans, improved methods of making traditional food products, and quality control.
5. Extension and educational campaigns promoting legume production and utilization and encouraging patterns of cooking and eating that include various legumes.

COOPERATING AGENCIES

The National Network of Research Centers, Stations for Legumes, and the National Center, University of the Philippines at Los Baños College, Laguna, all cooperate in these efforts. Cooperating stations are located at the University of Southern Mindanao; Mariano Marcos State University; Isabela State University; Palawan Agricultural College; Central Mindanao University; Tarlac College of Agriculture; Zamboanga National Agricultural College; Bureau of Plant Industry, La Granja, Negros Occidental; Bureau of Plant Industry, Economic Garden, Laguna; Bureau of Plant Industry, Mindoro; Bureau of Plant Industry, Pili, Camarines Norte; Bureau of Plant Industry, Ubay, Bohol; and Bureau of Plant Industry, Tupi, Cotobato.

Sri Lanka

H.M.E. HERATH

The cultivation of soybeans has been popular since 1973, when Sri Lanka realized the potential of the crop. Varietal introduction, multilocation testing, agronomic investigations, cultural practices, and the development of a package of practices gave the farmer the impetus needed. The extension effort became successful when utilization and processing research got under way. Unlike other traditional pulses which are consumed directly or partly processed, soybeans need heat treatment to inactivate antinutritional factors.

In the wake of import substitution programs, the awareness of nutritional problems has motivated the government to promote soybean production due to its many advantages. Major irrigation projects in the dry zone have helped crop specialists to evolve cropping systems that could use water not only for rice cultivation, but also for other high value crops. With massive investments in such projects, the cropping intensity has to be increased in order to make these programs economically viable. Of the crop options available for irrigable land, the most promising combination appears to be soybeans and rice. At the present time, the government has included soybeans with a few other field crops into a floor price system. During the last 12 months, the demand for soybeans has increased tremendously, with their use by some agencies in fortification programs.

Sri Lanka cannot boast of a massive acreage due to the constraints in utilization. However, there has been a substantial increase in recent years, from a few ha in 1973 to 6,000 ha in 1979. The synchronizing of production and consumption has taken time. Soybean production is now at the stage where acreage increases are possible. Utilization patterns and processing technology now are geared to an expanded production program, which is expected to treble the area under soybeans by 1981. With the establishment of solvent extraction facilities, the fortification of wheat and rice flour, and DSM (dried soya milk powder), there is an immediate demand for 30,000 ha of soybeans. This target will be achieved by 1982.

The bulk of the area under soybeans is presently confined to the rainfed highland. The north central part of the country has successfully adopted this crop to stabilize the lands which were used in the past for shifting cultivation. The cultivation techniques are simple but effective. Minimum tillage, using a hoe for scraping the weed cover, just prior to the advent of the northeast monsoon, is all the preparation tillage farmers carry out. Row seeding is achieved by using a hand-drawn marker and row dibbling. Herbicides are seldom used. Inoculum is the main source of nitrogen. Some farmers give a basic dose of 20:60:40 of N, P, & K. Sowing is carried out with the first rains in October. A seed rate of 60 lbs/acre gives an optimum plant population when spacing is 40 x 5 cm. The crop is mainly grown in rice fields under irrigation, where it follows a crop of rice. This appears to be the best rotation for the larger tracts of irrigable land in the dry zone.

Varietal improvement began with the INTSOY program in 1973, followed by the introduction of advanced breeding lines and selections for the different agro-ecological zones. A local breeding program was subsequently initiated, using some of the introductions and the local cultivars. The combined analysis data of ISVEX trials for 1975 and 1976 are shown (Tables 1 and 2).

Tracer studies with N & P showed distinct increases in yield with basal application of 20 kg N and 80 kg of P_2O_5 per ha. The chief source of N, however, was from the imported Nitragin inoculum. There has been no evidence of indigenous strains of *Rhizobium*.

Most farms are so small that mechanization is not possible. The only operation farmers carry out is weeding, which is done

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manually. Under irrigated conditions in the previously puddled rice fields, 3.5-4 acre-feet of water is required for a crop of soybeans during the months of May through September, when evaporation rates are as high as 6-9 mm a day.

There are no serious pests or diseases that threaten soybean cultivation. With increasing cultivation, however, the yellow mosaic virus may become a problem.

Yields vary with the two systems of cropping. Due to the uncertainties of the northeast monsoon, rainfed yields range from 840 kg to 1,550 kg/ha. Under irrigation the range of variation is low, and yields average around 2,500 kg/ha with existing cultivars.

Costs of production worked out for the two systems of cropping show that rainfed soybeans cost about Rs.1.10 and an irrigated crop about Rs.2.75 per kg.

Constraints to production have been mentioned previously. The development of a processing industry is the main limiting factor, since farmers' acceptance is largely dependent on disposal of a harvested crop.

The Sri Lanka Soybean Program is supported by FAO/UNDP, UNICEF, and CARE. This is a government-sponsored program headed by a project coordinator, carried out by the Department of Agriculture under the Ministry of Agricultural Development and Research, and channelled through the Agricultural Research and Extension Divisions of the Department. Seed production is handled by the Division of Seed and Planting Materials (Figure 1).

The primary objective of the Sri Lanka program is to develop a balanced soybean industry including production, marketing, processing and utilization.

Processing and utilization are integral components of the program. Considerable progress has been made in product development and the pilot plant demonstration of various prototypes since the establishment of the Soybean Food Research Centre (SFRC). A description of the major accomplishments of the Centre follows:

LIQUID SOYMILK. In order to determine the acceptability of liquid soymilk produced at the Soybean Food Research Centre (SFRC) pilot plant, a survey on the use of soymilk as a substitute of coconut milk was conducted in the Ampari district. With regard to taste, 87.4 percent of the samplers reported that soymilk is acceptable as a substitute for coconut milk.

DRIED SOYMILK. Nearly 5,000 lbs of dried soymilk (DSM) was manufactured at the SFRC pilot plant and sold through various outlets to determine its acceptance as a coconut milk extender/substitute. DSM has been found acceptable as a coconut milk extender by General Hospital in Kandy and Teaching Hospital in Peradeniya. The Rajarata Food Grain Processing Co., Ltd., a joint venture of the GSL and the private sector, is putting up a 4-ton FFSF/DSM plant in Maha Illuppallama, under the technical guidance of the staff at the SFRC.

FULL FAT SOY FLOUR. A feasibility report for a 20-ton/day Full Fat Soy Flour (FFSF) is under preparation by the Ministry of Plan Implementation, with technical guidance from the staff at the SFRC. Nearly 70,000 lbs of FFSF has been produced at the pilot plant and sold through various sales outlets for fortifying wheat/rice flour at 5-10 percent levels. Studies on optimization of process parameters, storage stability, and the levels of fortification of the wheat flour with FFSF have been conducted. The feasibility of using the existing rice milling and parboiling facility at Kundasale for the production of FFSF and rice-soy blends has been explored.

SOY-FORTIFIED BAKERY AND OTHER PRODUCTS. Levels of fortification of wheat flour with FFSF in bread, buns, biscuits, and noodles have been determined. Soy-fortified noodles are being successfully marketed by Forbes and Walker, a local company interested in soy products.

LOW COST WEANING FOODS. Low cost dry-formulated soy-based weaning foods (Soy-Rice-Sugar-V & M Premix and Rice-Soy-Green-Gram-V & M Premix) have been formulated and produced at the SFRC. The latter formulation is being evaluated at General Hospital in Colombo. The techno-economic feasibility of producing drum-dried weaning food is being investigated by the Darley Butler Co. under the technical guidance of the staff at the SFRC.

TOFU. Regular production of about 20 lbs of tofu per day has been done with a view to testing its acceptance for use in various curry preparations. Studies relating to the optimization of process parameters to maximize yield, shelf life, texture, and flavor characteristics are being conducted. Base data are being collected through pilot plant trials for the preparation of techno-economic feasibility reports on tofu production on a cottage scale.

TEMPEH. Processing parameters for the production of tempeh at the cottage scale have been standardized. Various methods of extending shelf life have been investigated.

SOY DHAL. Quick-cooking soy dhal, comprising 80 percent soy and 20 percent corn, has been extrusion cooked in a Brady cooker and market tested by two local distributors. Further trials and extensive market testing will take place after the arrival of an Insta-Pro extruder.

HOME LEVEL TRAINING AND DEMONSTRATIONS. Home level training and demonstrations of the uses of soybeans have been conducted at all trainee levels. By May, 1981, 1,077 trainees had followed the one- to two-week regular course, and 483 had completed the "Sandwich Course." More than one hundred demonstrations have involved about 6,000 participants, both from governmental and voluntary organizations. Since February, 1981, the two-week training course has been integrated with the FWAE program for the KVSS of the Department of Agriculture. A total of 89 KVSS had completed this training by the end of May, 1981. A two-day sandwich demonstration and training course has been arranged for the teachers of the Government English Training College at Peradeniya and the Nurses' Training College at Kandy. A total of 116 from this group have undergone training.

The Soybean Food Research Center, with the addition of infra-structural facilities, has the potential of developing into a full-fledged food research institute which can not only adequately handle problems of post-harvest technology of food crops in the country but also become an excellent center for postgraduate training in food technology.

Substantial financial and technical assistance has been provided by GSL/UNDP/FAO/UNICEF/CARE/INTSOY during the last 5 years. With some additional input in terms of continued support from the national and international agencies, it is hoped the Sri Lanka Soybean Development Program will not only meet the objective—to provide better nutrition for the malnourished target groups—but also serve as a model for developing countries in solving their nutrition problems.

Table 1. Combined Analyses of Sri Lanka Sites - ISVEX 3, 1975 (Average of 10 Experiments)

Cultivar	Yield (kg/ha)	Days to flower	Days to maturity	Plant height (cm)	100-seed weight (g)
Hardee	2,938	33	98	38	17.8
Davis	2,740	31	96	34	18.9
Bossier	2,578	35	96	43	17.4
Bragg	2,493	31	93	36	19
Forrest	2,448	30	91	35	16
Williams	2,441	28	87	41	20.2
Improved Pelican	2,404	36	96	67	14.7
Ph-1	2,370	33	88	46	13
Sj-2	2,355	36	97	61	14.6
Hampton 266A	2,275	30	93	30	20.4
Tracy	2,224	28	86	30	19.3
Clark 63	2,194	30	86	48	18.1
Jupiter	2,187	41	108	65	19.2
Bonus	2,033	28	89	37	19.6
Hill	1,969	31	88	35	16.2
Grand mean	2,377	32	93	43	18
SE of CV mean	122.17	86	1.17	2.31	.43
CV	32.5%	17%	8%	33.9%	15.5%
5% of LSD CV means	341.9	2.4	3.3	6.5	1.2

Table 2. Combined Analyses of Sri Lanka Sites - ISVEX 4, 1976 (Average of 10 Experiments)

Cultivar	Yield (kg/ha)	Days to flower	Days to maturity	Plant height (cm)	100-seed weight (g)
Davis	2,726	30	101	34	18.8
Forrest	2,610	28	91	35	14.5
Williams	2,537	26	89	46	18.6
Bragg	2,477	29	97	41	17.7
Bossier	2,418	31	96	37	16.8
Improved Pelican	2,415	33	100	75	14.3
Clark 63	2,351	28	87	48	17.1
Hill	2,287	30	92	37	15.7
Jupiter	2,171	38	117	69	17.8
Grand mean	2,444	30	97	47	16.8
SE of CV mean	139.58	1	1.99	2.57	.38
CV	36.1%	20.9%	13%	34.7%	14.3%
5% of LSD CV means	NS	2.83	5.63	7.25	1.07

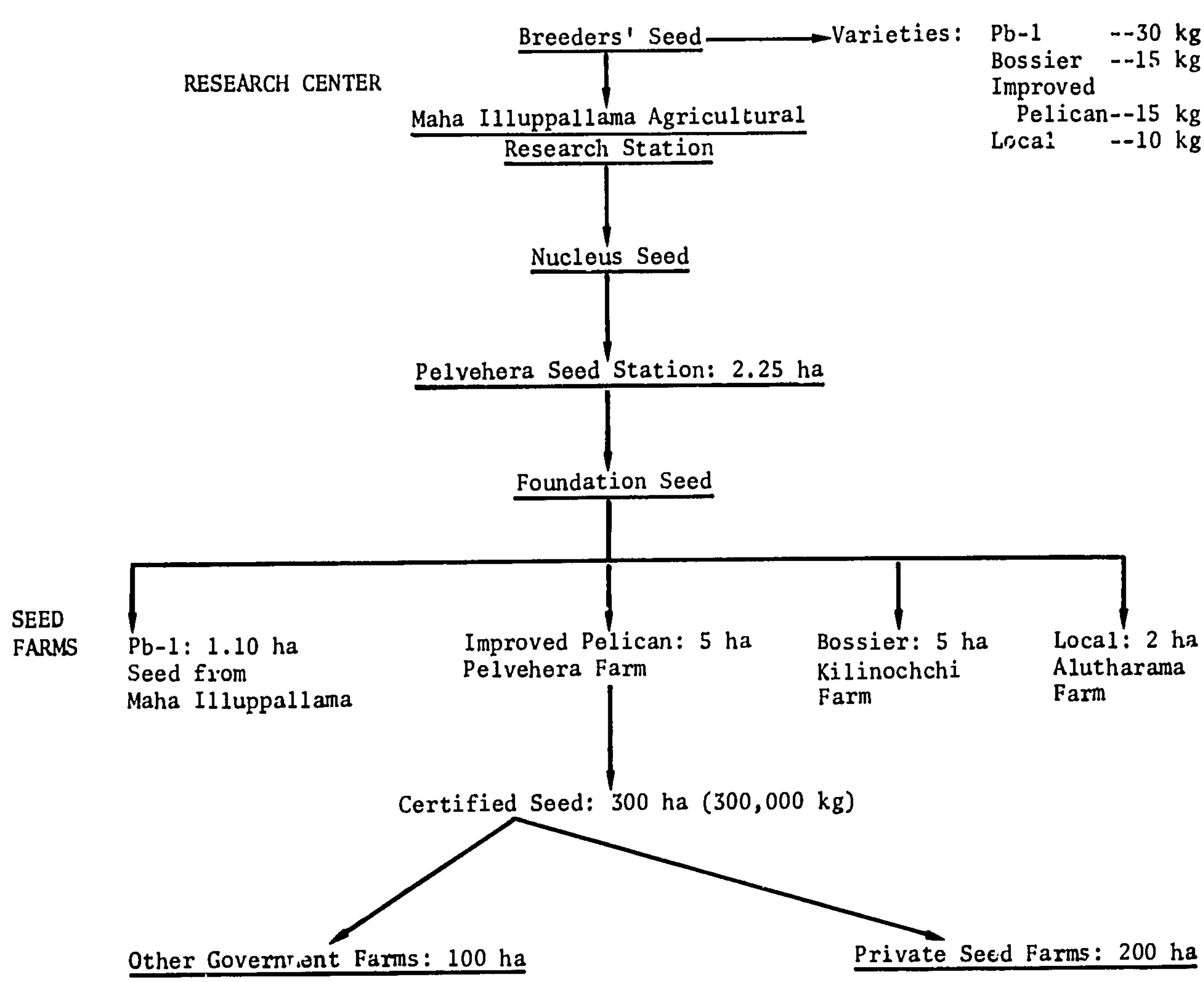

Figure 1. Sri Lanka certified soybean seed production program. (Target: 300,000 kg of certified seed per season.)

Thailand

AMNUAY TONGDEE

Soybeans are one of the most important economic crops of Thailand. They are grown mostly in the northern region, with the largest area in Sukhothai and Chiang Mai Provinces.

Sukhothai Province lies in the northern part of the central plain, in the basin of the Chaophya River, and includes undulations leading to the northern mountainous area, so that it may be classified as an intermediate area of the central plain. Nearly 70 percent of the total area under soybeans in Thailand is in the Sukhothai area, where soybeans are grown as an upland crop in the rainy season. The farmers in Sukhothai are far more enthusiastic about soybeans than those in Chiang Mai.

Chiang Mai is situated in the northern part of Thailand and constitutes the so-called northern inland high (19° N, 300m above sea level). In both area and production of soybeans, it is next only to Sukhothai Province. In Chiang Mai, soybeans are generally a sequence crop following the rainy season crop of rice.

AREA AND PRODUCTION

Statistics on the area and production of soybeans in Thailand have been compiled by Thailand Agricultural Statistics, Division of Agricultural Economics, Ministry of Agriculture and Cooperatives. Figures on both area and production fluctuate significantly from year to year. Demand for grain legumes, especially soybeans, has increased rapidly due to the expansion of oil extraction and feed industries. The government of Thailand included soybean production in the accelerated development programs in the third 5-year plan (1972-1976) and set a target of 300,000 tons for 1976. The actual production in 1976, however, was only 113,600 tons. For the fourth 5-year plan (1977-1981) the target was 431,000 tons in 1981 (Table 1).

PRODUCTION TECHNOLOGY

Cultural practices in the cultivation of soybeans, including land preparation, sowing, and care of the crop (depending on type of soil, topography, and irrigation availability) differ from region to region.

In the north, plowing and hilling-up is done in 65 percent of the area by manual labour and in 35 percent by tractors. In contrast, farmers in the central region use tractors in 95 percent of the area for plowing, which is done once or twice. Whether tractors are used or which type of plow is chosen depends on the characteristics of the soil and its moisture content. In hard soils, 3-disc plows are used; in loamy soil or sandy loam, 7-disc harrows are used. Two plowings give the best results.

Soybeans are grown both as a sole crop and as a relay crop. The seed rate is 38 kg/ha. Rows are set 50cm apart and hills are 20cm apart. In the north, where soybeans are grown after rice, sowing is done from December through January. In some cases, spacing is about 30 x 20cm, which requires about 52 kg of seed/ha. In the central plain soybeans are a sequence crop after rice and are planted from November to January, depending on the duration of rice and the availability of irrigation facilities. In the northeast soybeans are planted with the first soaking rain, usually in May but sometimes as late as July, while spacing is 50 x 20cm. Soybeans mature 100-120 days after sowing, and harvesting is done manually. Threshing is by hand or animal power, and sometimes by machine.

The cultivars grown commercially are S.J.1, S.J.2, and S.J.4. (S.J.5 is a recent recommendation). These cultivars have a high yield potential and are of excellent

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seed quality, while tolerant to diseases such as rust, bacterial pustule, and downy mildew.

In order to increase the production of soybeans in Thailand, plant nutrients must be supplied either through fertilizer, green manure, or animal manure. An application of 20-60-40 kg/ha is generally recommended for obtaining top yields and maintaining soil fertility. Cattle manure is used widely in the northern region, especially when soybeans are grown under irrigation following rice.

Because of the specificity of the *Rhizobium*, the inoculation of soybeans is necessary on new land. In the northern region, where soybeans have been grown for a long time, inoculation does not appear necessary. Farmers are advised not to inoculate with *Rhizobium* except on new land which has never been planted with soybeans.

Soybeans can be planted throughout the year. The factors that determine the time of planting are soil moisture, anticipated rainfall, and the weather at harvest.

The crop is usually grown under irrigation in the northern part of Thailand. The most suitable time of planting in this region is December through January, so that the crop can be harvested in April in order to avoid damage by pre-monsoon rains.

This rainy season crop is the most important one. It accounts for about 80 percent of all soybean production, which takes place mostly in the northern part of the central plain. Planting is done in late April or early May.

Cropping Patterns

Soybean-based cropping patterns are one of the important means of improving soybean production in this country. Since soybeans have a short growing season (100-120 days), they are suitable for inclusion in the major cropping systems either as enter, relay, or sequence crops.

The various soybean-based cropping systems followed in Thailand are discussed in a paper presented by Dr. Arwooth at this meeting and will not be elaborated here.

Pests and Diseases

Insects are more damaging to soybeans than diseases. However, the number of devastating insects that need special attention is not large. One such pest is the beanfly (*Melanogromyza spp.*), maggots of which live and feed inside the soybean seedling.

The most common diseases are rust (*Phakopsora pachyrhizi Syd.*), downy mildew (*Peronospora manshurica* Naoum.), anthracnose (*Colletotrichum dematium*), bacterial pustule (*Xanthomonas phaseoli*), root rot (*Rhizoctonia solani*), and soybean mosaic virus.

SEED PRODUCTION PROGRAM

An important prerequisite to increasing the production of soybeans is the seed multiplication of high yielding cultivars with wide adaptability. Towards this end, the government, in cooperation with the private sector, set up a 5-year program of soybean seed production with a goal of 660 tons in 1977 and 14,255 tons in 1981. In spite of the best efforts of the government agencies (the Department of Agricultural Extension and the Department of Agriculture) and the private sector (including farmers' associations and seed companies), the goals have not been achieved. At present government agencies can produce good seed in sufficient quantities to meet only about 3 to 5 percent of the demand.

Constraints

One of the major constraints to soybean production is the uncertain weather. In the worst year, 1977, the rainfall was abnormally low and also, consequently, the inflows into reservoirs. Thus, both the rainfed and irrigated crops were severely affected.

Improper storage of seeds and limited irrigation are also major constraints to the production of soybeans in Thailand. Soybean seeds lose viability within 3 to 6 months after harvest when stored at room temperature in average relative humidity. In the absence of refrigerated storage, seed has to be produced in the dry season for the main crop in the rainy season. Since irrigation in the dry season is limited, only enough good quality seed is produced for about 3 to 5 percent of the area.

At present, price and demand are determined by the middleman, both in the central market and the local market. Fluctuation in demand, as well as price, is high (Table 2).

The majority of farmers follow traditional practices of growing soybeans. Improved technology is not yet widely available, so the result is low yield and production. The new extension program has not yet reached most farmers.

ORGANIZATION

Soybean research activities emphasize breeding, cultivar improvement, soil fertility, and pest control. Government agencies include the Department of Agriculture, the Land Development Department, Kasetsart University, Chiang Mai University, and Khonkaen University.

The Department of Agriculture, under the Ministry of Agriculture and Cooperatives, has been promoting large-scale production of soybeans. Their major emphasis is on increasing both yield and acreage and improving soil fertility. Thai farmers have responded positively, as shown by the expansion of the area under soybeans from year to year.

The soybean research program under the Department of Agriculture is included in the "Oil Crops Project" handled by the Field Crop Division of the Department of Agriculture. Other government agencies, such as universities and academic institutions, conduct similar research.

The main agency responsible for our soybean research program is the Department of Agriculture in the Ministry of Agriculture and Cooperatives. Facilities for this program are provided by government and other sources at the Agricultural Experiment Stations. Among these, Mae-Jo Agricultural Experiment Station is the key station for our soybean improvement program.

DISCUSSION

W.M.S. Bowatte: How do your farmers get the soybean seed they need for planting?

A. Tongdee: Our farmers get seed either from the government agencies responsible for our program, such as the Department of Agriculture and the Department of Agricultural Extension, or from merchants.

W.M.S. Bowatte: How does the seed multiplication scheme operate?

A. Tongdee: The Department of Agriculture and the Department of Agricultural Extension conduct the soybean seed multiplication program, sometimes with the cooperation of merchants, farmers' organizations, and other groups in the private sector.

C.L. Wang: Have you ever found any wild soybeans (that is, *soja*) in Thailand?

A. Tongdee: Although the soybean program was started quite a long time ago in Thailand, and we have introduced from 2,000 to 3,000 cultivars or lines from other places, we have found no wild soybeans as yet.

Table 1. Soybean Production in Thailand, 1970-1979

Year	Area (1,000 ha)	Production (1,000 tons)	Yield (kg/ha)
1970	58	50.4	850
1971	57	54.3	944
1972	80	72.0	900
1973	123	104.2	850
1974	132	110.4	838
1975	119	113.9	963
1976	102	113.6	1,120
1977	153	96.2	632
1978	162	158.9	981
1979	108	102.1	938

Source: Office of Agricultural Statistics, 1979 Annual Report.

Table 2. Production Costs and Profitability of Grain Legumes and Competing Crops

Crop	Cost of production (U.S.$/ha)	Yield (kg/ha)	Farmers' receipts (U.S.$/kg)	Net profit (U.S.$/ha)
Soybean, grain	153.40	628.6	0.33	54.04
Groundnut, pods	253.04	1,575.6	0.23	109.35
Mungbean, grain	102.32	475.4	0.32	45.05
Virginia tobacco	713.30	10,937.5	0.11	471.82
Onion, dry	1,253.22	4,543.3	0.51	1,063.87
Garlic, dry	857.50	2,312.5	0.49	275.62
Off-season, paddy rice	250.43	3,325	0.1	82.07
Sweet corn, ear	266.97	20,106	0.02	135.15
Tomato, fresh	358.41	12,500	0.05	266.59
Turkish tobacco	615.03	984.4	0.69	64.23
Watermelon	70.26	1,000	0.12	49.24
Green pepper, fresh	492.63	1,893.8	0.25	19.39

Note: Except for peanuts and green gram, the other crops do not really compete with soybeans for the same land, either because they are irrigated and/or have a limited market.

Turkey

Y. ZIYA KUTLU

Turkey lies between Asia and Europe at 36°-42° N latitude. The area of the country is about 78.1 million ha. The total cultivated land is 24.5 million ha, 16.5 million of which are under cultivation every year. The remaining 8.5 million ha are fallow. The major crops are cereals, followed by industrial crops, oil crops, and pulses. The annual rainfall is about 600 mm in the Mediterranean and 1,000 mm in the Black Sea region. The Central Plateau and the Eastern Highlands receive less than 400 mm a year. The coastal areas have a typical Mediterranean climate, where the rainfall occurs between October and May. From June to September it is very dry, with the exception of the East Black Sea coast, where the total rainfall is over 2,000 mm and is very well distributed throughout the year.

The population of Turkey is about 45 million, with a rate of increase of 2.3 percent per year. Turkey is self-sufficient in its nutrition, with 65 percent of its total export income from agricultural products, except for soybean oil, which has to be imported.

PRODUCTION TECHNOLOGY

Soybean production started in the 1940s. The growing area and amount of production is shown in Table 1. In the East Black Sea region soybeans are sown as a monocrop and intercropped with maize. Soybeans will be an important crop in the double cropping system in the South and West of Turkey in the future. There are 1.2 million ha of irrigated land for growing cotton and wheat in the coastal region. The soil preparation and soybean sowing should be completed just after the harvesting of wheat, i.e., from the beginning of June to June 15th. Experiments have shown that this procedure is gainful both for growers and the national agricultural income. Soybeans also can be an important crop in sugar-beet-growing areas through rotation. The sugar beet is cultivated in an area of 270,000 ha in transitional zones and the Central Plateau, and at least 50,000 ha of this area can be rotated with soybeans each year.

Only introduced cultivars are used in soybean production in Turkey. In the East Black Sea region, Clark-63 dominates as a commercial cultivar, because of earliness and resistance to white flies. Another introduced cultivar, Amsoy-71, is preferred in the Adana region (Mediterranean). Calland and Williams are the promising cultivars for the Aegean region (Table 2).

Optimal seed rating is 50 to 60 kg/ha. Nitrogen at 60 kg/ha and phosphorus at 60 to 80 kg/ha are used. The Soil and Fertilizer Research Institute produces and distributes 1,000 kg of *Rhizobium* inoculum each year to the farmers at a rate of 1.5 kg inoculum per 100 kg soybean seeds at sowing. The Institute found that eight strains of *Rhizobium* fix nitrogen very effectively.

Agriculture in the coastal Black Sea areas is not mechanized. Seeding, cultivation and harvesting are managed by hand. But in the South of Turkey, from seeding to harvest, all production methods are mechanized. Combined fertilizer and seed drills are used for planting. Cotton inter-row cultivators are used for weed control. Harvesting is done with normal cereal combines.

Because of the sufficient precipitation, additional irrigation is not necessary in the coastal Black Sea region, but in the South and the Aegean regions, after wheat harvesting, it is not possible to plant soybeans without irrigation. During growing season, from the flowering to the pod filling stage, 2 to 3 times of irrigation is necessary to get the optimum yield.

Fungal diseases in the Black Sea region and insect damage in the Mediterranean region are common. Several fungicides and

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insecticides are used during the vegetative period. Amsoy-71, which is resistant to the white fly, is planted in the Mediterranean region.

As mentioned before, the soybean is an introduced plant. Therefore, it is necessary to gather some experimental data on how soybean cultivars perform under different agro-ecological conditions. Agricultural Research Institutes conduct uniform cultivar trials. After finding a suitable cultivar, the research institutes supply seed to the state farms. Then, state farms give the multiplied seed to the extension services for distribution to the farmers. This year the Turkish Government is importing nearly 3,500 tons of soybean seeds from the U.S.A. to start the program.

There is much variation in the yield of soybeans. The lowest average was 1,022 kg/ha in 1977, and the highest average was 2,429 kg/ha in 1974. The 10-year average is 1,502 kg in the Black Sea region. Yields from experimental plots are 3,500 kg. We expect the yield levels to be from 2,000 to 2,500 kg/ha in the Mediterranean and Aegean regions, as a second crop. To know whether soybean growing is economical for the farmer, it is necessary to make comparisons with other competing crops for economic returns (Table 3).

Soybeans compete well with other crops, as shown, with about 21,000 TL/ha.

In the Black Sea coast area, farmers have been unable to get a good price for soybeans as the only processing plant in the city of Ordu insists on a maximum moisture content of 15 percent. But it is very difficult to maintain a 15 percent moisture content, as the climate throughout the season is very humid. This factor has become a serious constraint to improving soybean production in the Black Sea coast area.

ORGANIZATION

The Soybean Development Project is conducted by the Ministry of Agriculture and Forests in coordination with the General Directorate of Agricultural Research and Agricultural Affairs and the State Multiplication Farms. Breeding, original seed multiplication, and the development of new cultural practices are under the auspices of the General Directorate of Agricultural Research. Extension Services distribute multiplied seeds to the farmers and also educate them.

Research on soybean improvement is conducted by four Agricultural Research Institutes. Five technical staff members work on this project, two with a Ph.D. in general plant breeding, the others at the B.Sc. level. As soybean production areas are increased in the future, problems may appear. Therefore, it is necessary to add and train more researchers for this project.

Table 1. Growing Areas, Yield, and Production of Soybeans in Turkey

Years	Growing areas (ha)	Yield (kg/ha)	Production (tons)
1970	11,000	1,091	12,000
1971	7,000	1,571	11,000
1972	6,000	2,133	12,800
1973	5,070	1,460	7,400
1974	3,500	2,429	8,500
1975	6,200	1,089	6,750
1976	6,470	1,328	8,500
1977	5,400	1,022	5,500
1978	3,200	1,155	3,400
1979	1,500	1,300	1,950

Table 2. Recommended Cultivars for the Regions of Turkey

Black Sea (Samsun)	Mediterranean (Adana)	Aegean (Izmir)
Clark-63	Amsoy-71	Williams
Calland	Calland	Amsoy
Cutler	Mack	Harcor

Table 3. Economic Returns from Soybeans and Other Competing Crops in Turkey

Crops	Avg. yield (kg/ha)	Government price support (TL/kg)	Gross income from support (TL/ha)	March, 1980, market price (TL)
Wheat	1,789	5.30	9,481.70	23,251.00
Sunflower	1,236	16.75	20,703.00	37,080.00
Maize	2,192	10.00	21,590.00	32,880.00
Soybean	1,502	14.00	21,028.00	None on market

Abstracts of Contributed Papers

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The Effect of Soybean Seed Protein Content on Growth of Seedlings

H.F. Chin

High protein content in seeds is an attribute of seed quality which can be improved by supplementary nitrogen. Soybean plants responded to supplementary nitrogen application, producing seeds of greater weight and protein content. Seedlings from high protein content seeds were more vigorous and higher in total dry matter than those from low protein content seeds. The relative growth rate, net assimilation rate, and leaf area ratio of seedlings were compared from 8 to 28 days after planting. Results showed significant differences between seedlings from high and low protein seeds.

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The Major Factors Affecting Quality of Soybean Seeds in Nigeria

M.I. Ezueh

Experimental work has indicated that successful soybean crops can be obtained in both the early and the late seasons, though the early season crop is of lower quality. Insect damage, disease incidence, and climatic factors (especially temperature and relative humidity) are the major factors influencing seed quality and ultimate viability. The most common insect pests are the pod-sucking bugs, especially *Nezara viridula* and *Piezodorus* spp. Considerable seed damage is also done by *Cydia ptychora*. Major diseases of soybeans include *Cercospora* spp., *Diaporthe phaseolorum* var. *sojae*, *Khuskie oryzae*, *Fusarium* spp., and *Phoma sorghina*. Breeding for insect and disease resistance, as well as storage under adverse conditions, would enhance the production of soybeans in Nigeria and other tropical countries where production by modern methods is still elementary or nonexistent.

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Soybean Research, Production, and Demand in Venezuela

Humberto J. Fontana N.

Soybean research in Venezuela has attained a high level of organization, with excellent coordination among the institutions involved. It is very probable that in a few years we may have enough genetic material to develop or improve cultivars with good adaptation to tropical conditions. A significant advance in agronomic research has made it possible to produce soybeans with an acceptable yield of about 1.5 quintals/ha when planted during the rainy season. Under irrigation, yields of 2.0 quintals/ha have been reached, but the high cost of irrigation increases prices to a level of Bs3.00/kg (US$0.70/kg), about twice the price of corn (US$0.27/kg). The easiest and least expensive way to improve the diet of school children is by using soybean meal as an enricher of cornbread and beverages. We must establish better international networks to develop tropical cultivars of soybeans; we hope to strengthen our relations with programs such as the International Soybean Program (INTSOY) at the Universities of Illinois at Urbana-Champaign and Puerto Rico, Mayaguez.

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Soybean Germination Problems in Uganda and Current Investigations

Flavia Kabeere

The establishment of the Uganda Seed Multiplication Scheme in 1971, with the objectives of producing, bulking, and planting seeds of high quality, should have meant the boosting of soybean seed production. However, large scale production of the legume re-introduced the problem of poor seed quality. The poor germination of soybeans in the field led to large losses and made the crop unpopular with farmers. Observations made during routine laboratory tests showed that seeds germinating poorly were often discolored, while seed moisture content was usually low, ranging from 9 to 12 percent. The germinating seedlings and ungerminated seeds were usually covered with an abundant growth of *Rhizopus* sp. and other storage fungi. Bacterial growth was common on decaying seeds and seedlings. Freshly harvested seeds were heavily invaded by storage fungi, especially *Aspergillus glaucus*, *A. flavus*, *A. ochraceus*, and *A. niger* groups; *A. oryzae*, and *Penicillium* spp. Due to the thick growth of *Aspergilli* and *Penicilli* and sometimes of *Rhizopus* sp., bacterial growth was observed only on surface-disinfected seeds. *Bacillus* spp. have been commonly isolated from decaying soybean seeds and seedlings. Storage fungi caused a decrease in germination. The percentage of seeds colonized by *Rhizopus* sp. and bacteria increased with increased storage time. These microorganisms are thought to contribute to the loss of seed viability. The germination of soybean seeds inoculated with *Aspergillus* spp. and *P :icillium* spp. decreased as the storage period increased under laboratory and cold room conditions. The microflora most commonly associated with freshly harvested seeds were *Cladosporium* spp., *Fusarium* spp., bacteria, *Aspergillus* spp., and *Penicillium* spp. Invasion by *Cladosporium* spp. alone did not cause abnormality of seedlings or death of seeds.

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Comparison of Rates of Field Deterioration of Mack, Dare, and Forrest Soybean Seeds

M.B. Mohd. Lassim and J.C. Delouche

Foundation seed of Dare, Forrest, and Mack soybean cultivars were planted in adjacent plots. Beginning on the date of field maturity and at weekly intervals for the following 9 weeks, a sufficient number of pods were hand stripped from randomly selected plants to provide about 1 kg of air-dried seeds from each cultivar. These samples were used for quality evaluation tests of germination, accelerated aging, tetrazolium (germination potential and germination energy), and field emergence. The results clearly indicate that Mack seeds were more adversely affected by delays in harvest and weathering than Dare and Forrest seeds. At the time of field maturity, seeds of the three cultivars germinated 90 percent or higher. Despite the exceptionally good weather during the dry-down period, germination of Mack seeds dropped from 80 to 68 percent between the third and fourth week after maturity. Seeds of Dare and Forrest cultivars, however, remained above 80 percent germination until over 6 weeks past maturity. Mack seeds harvested 6 weeks after maturity germinated only 62 percent, or 18 percent lower than Dare or Forrest. Thus, Mack seeds dropped in germination to below 80 percent just 3 weeks after field maturity, while Dare and Forrest seeds maintained germination at 80 percent or higher for 6 weeks after field maturity under the same field conditions. It appears, therefore, that seed of the Mack cultivar is inherently more susceptible to weathering than seed of Dare and Forrest.

DISCUSSION

E. Pili: You have used two words—tetrazolium potential and tetrazolium energy. What is the difference between the two, please?

M.B.M. Lassim: Tetrazolium test responses were scored in accordance with Moore's classification, in which seeds are divided into 8 classes. Class 1 to class 5 are potentially germinable. Class 1 represents seeds with sound embryos, while class 5 represents seeds of near critical degeneration with respect to seed potential germination. Classes 6 to 8 are nongerminable. Tetrazolium energy was obtained by totalling the number of embryos in classes 1, 2, and 3. These classes represent a group of vigorous seeds.

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Survey of Fungi Associated with Soybean Seeds in the Philippines

F.C. Quebral and . .V. Prado, Jr.

Seventeen fungal genera were isolated from the different soybean seed samples collected from various experiment stations. Among them were *Alternaria, Aspergillus, Botryodiplodia, Cercospora, Chaetomium, Colletotrichum, Curvularia, Fusarium, Gloeosporium, Mucor, Phaeotrichoconis, Phoma, Phomopsis, Pithomyces, Penicillium, Rhizoctonia,* and *Rhizopus*. The high occurrence of storage fungi obtained from assayed seed samples is indicative of the influence of the environmental conditions to which these seeds were exposed. Most of the storage fungi isolated were members of the *Aspergillus glaucus* and *A. flavus* groups. The field fungi identified to be associated with seed samples were *Alternaria, Botryodiplodia, Cercospora, Colletotrichum, Curvularia, Fusarium, Gloeosporium, Phaeotrichoconis, Phoma, Phomopsis, Pithomyces,* and *Rhizoctonia*.

The vigor index and the germination percentage values of the assayed seed samples were found to be relatively low. The seed association by the field fungi might have been brought by way of the flowers, cracks in the pods, and by direct penetration. Preliminary screening of chemicals to increase seedling stand showed that Captan 50-WP, Daconil 2878, Vitavax, and Arasan 50 gave more significant results than the control.

DISCUSSION

P.S. Bhatnagar: It was said in the report that through comparison cropping the incidence of disease and pests on soybeans is reduced. How can this be explained?

F.C. Quebral: The flight patterns of some insects, such as aphids, are altered in intercropping, as when soybeans are intercropped with either sugar cane or corn. We have also found some evidence of predators in an intercropping scheme.

B.K. Divetia: One of the studies showed yearly market prices. There was a phenomenal increase in prices from 1976-77. What were the reasons for that 80 percent increase in one year? Was it that demand was high and supply low, or was it something else?

F.C. Quebral: The year 1976 was the last year for the soybean support program under the white corn and feed grains programs. After that year the credit component was withdrawn, soybean hectarage was reduced, and monitoring was suspended.

A. Sajjapongse: What is the reason for applying fertilizer in the dry season but not in the rainy season?

F.C. Quebral: In the first place, yield during the wet season is low compared to the dry season. The farmer covered by the program might not be able to pay the cost of inputs because of the risks, and therefore a low technology (just with inoculation) is being recommended.

A. Sajjapongse: Heavy rain causes high leaching, making the soil less fertile. Eventually there is a lower yield if fertilizer is not applied. Perhaps it would be better to apply fertilizer and split it many times to avoid leaching.

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Rate of Development and Oviposition of *Callosobruches chinensis* L. in Different Cultivars of Soybeans

Rohan H.S. Rajapakse and V.K. Kulasekera

The rate of development and oviposition of *Callosobruches chinensis* L. (Bruchidae: Coleoptera) while attacking soybeans was studied with the use of different cultivars available at the laboratory. The local soybean cultivar was considered relatively resistant to beetle damage during the prolonged developmental period of the pest. Cultivars Bossier, Bragg, Davis, SJ-2, Improved Pelican, Pb 1, and Tk 5 were highly susceptible to the beetle attack. In all experimental conditions, most of the eggs were laid by *C. chinensis* on the first day of free adult life.

DISCUSSION

S. Shanmugasundaram: At AVRDC we have greengram and soybeans, but the *Callosobruches chinensis* attacks only greengram but not soybeans. Do you know whether the *Callosobruches chinensis* has strains or variations, so that some probably attack both soybeans and mungbeans while others attack only one of them?

R.H. Rajapakse: There may be different strains of *Callosobruches chinensis* in different countries, but we have not gone into the taxonomic aspects. We have only studied the *Callosobruches chinensis* found in Sri Lanka. I found the cultivars tested in this study were inhospitable to the *Bruchidae* sp. attack. Although I do not know about the strains of *Callosobruches chinensis*, there is a probability of their existence.

B.B. Singh: How much was the dry weight loss in soybean cultivars due to *Bruchidae* sp. infections?

R.H. Rajapakse: This effect was not studied, but as a personal observation I have seen 60-70 percent dry weight loss due to the *Bruchidae* sp. attack.

Rohan H.S. Rajapakse and V.K. Kulasekera are Agronomists, Department of Agronomy, Faculty of Agriculture, Ruhuna University, Mapalana, Sri Lanka.

Yield-Density Relationship and the Importance of Stand Establishment for Soybeans in Rice Stubbles

Kanok Rerkasem, Sakda Chongkaewwattan, and Sudtanom Homdork

Drilling soybeans directly into rice stubbles without land preparation is a commom practice in the North Thailand intercropping system of rice followed by soybeans. In farmers' fields stand establishment can vary considerably, from 16 to 96 plants/m^2. Two field experiments were undertaken to study the agronomic backgrounds of direct-drilled soybeans. In the first experiment S.J. 4 was established for densities of 4, 8, 16, 32, 64, and 128 plants/m^2. The optimum density range for grain yield was found to be 16 to 64 plants/m^2, giving the average yield in the order of about 200 gm/m^2. The maximum yield of 210 gm/m^2 was recorded at the stand density of 32 plants/m^2. An examination of the yield components (pods per plant, seed per pod, and individual seed weight) showed pods per plant to be the only component reduced when density was increased. The contributions of this component and final plant numbers became critical when the stands were established beyond 64 plants/m^2. At the highest stand density only 50 percent of the plants survived at maturity, giving the yields in the order of 135 gm/m^2 or 35 percent less than the maximum yields. In the second experiment soybeans were established at three densities (8, 32, and 256 plants/m^2) under six duration of weed competition treatments (0, 26, 42, 63, 70, and 120 days after sowing soybeans). Grain yield of soybeans was more markedly decreased the longer the crop remained weedy, with the sharpest reduction if the crop remained infested 42 days after sowing. Yield reduction of more than 30 percent occurred if the weeds were not removed until 63 days after sowing. When the weeds were removed within 42 days after sowing, the yield loss was less than 10 percent. There was no interaction between effects of weed and plant density. With or without weeds, optimum yield was obtained at 32 plants/m^2, in agreement with results from experiment 1. The results suggest that stand establishment is highly critical for maximum yields.

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Effect of Soil Moisture and Spacing on Germination and Yield of Soybeans

A. Sajjapongse and Y.C. Roan

Three experiments were carried out to determine the effect of soil moisture on the germination and emergence of soybeans and to study the effect of different spacings on soybeans planted with constant population density. The spacings between and within rows were 25, 50, 75, and 10, 20, 30 cm, respectively. With the constant population density of 400,000 plants/ha and nine factorially combined treatments, the number of plants per hill varied from one to nine. Although not significantly different, seed yields increased as the distance within rows became narrower. The highest yield was obtained from the 10-cm spacing. On the other hand, the best between-rows spacing was 50 cm. Yield was reduced when the distance between rows was either narrower or wider than 50 cm. The best spacing treatment from this study was 10 x 50 cm with two plants per hill. The yield difference was attributed to difference in seed numbers, seed weight, pod number, and number of branches per plant. The effect of soil moisture on the germination and emergence of soybean seeds was very pronounced. The soil moisture limit for seed germination was between 11.5 and 26.2 percent whereas the optimum moisture was about 18 percent. With higher soil moisture levels (25.8 to 29.3 percent) pathogenic organisms developed on the seeds, while there was no germination from the dry treatment. Under field conditions, the emergence of soybeans was observed daily. The results were very similar to the germination study. Emergence rate was reduced when soil moisture was either too wet or too dry. The soil moisture limit for emergence was 11.25 to 25.5 percent with the optimum at 17.5 percent. The highest emergence rate was found on the fifth day after seeding.

DISCUSSION

M.E.R. Pinto: In your flooding experiment, you said planting was done over a period of time--as I heard it, 20 days. Are you quite sure that there were not other factors affecting the experimental results due to this lag period? Also, at what depth was the soil moisture determination made?

A. Sajjapongse: The experiment was conducted for only 10 days, not 20 days. With this short period of time, we are quite sure that the only factor that affected soybean emergence was soil moisture.

During the period of study, there was no adverse environmental change. The soil moisture content was taken at 0 to 10 cm depth.

C.L. Wang: Is there any effectiveness of the temperature on germination of seeds when the water content of seeds is around 50 percent?

A. Sajjapongse: I believe there is interaction between temperature and the moisture content of seeds. A minimum specific seed moisture content of 50 percent is required in order to get seed germinates at certain temperatures. But when the temperature changes, the specific moisture for germination would change also. However, further research is needed to verify this.

R.F. Gretzmacher: What type of soil was used in the germination experiment?

A. Sajjapongse: It was sandy loam texture with 70 percent sand and 17 percent clay.

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The Effect of Sowing Methods on Plant Stand and Soybean Yield in Different Seasons

S. Shanmugasundaram, Yen Chung-Raey, W. Gunawan, and T.S. Toung

Soybean yields depend on a number of factors. Plant stand is one of them, and it varies with sowing method and other practices. In Indonesia and Thailand, soybeans are generally planted by broadcasting; plant stand is poor and the average yields are low. The object of this study is to understand the influence of sowing method on plant stands and yields in different seasons and with different cultivars, so that a suitable sowing method can be suggested for optimum yields. A total of five experiments were conducted in three seasons. Soybean seeds were sown in the field, either with or without tillage, after the rice harvest. Normal and double seed rates were tried. Normal seeds and presoaked seeds were compared for broadcasting, and rice-straw mulching was compared with no mulching. Spaced sowing and drilling were also tested. Large- and small-seeded cultivars were compared in some experiments. An experiment in February tested spaced sowing and drilling, and showed that better plant stand and yield were achieved with the two cultivars tested than could be obtained by broadcasting, either with or without mulch. In the summer season, broadcasting the seeds in a tilled field, with or without the use of mulching, gave better plant stand with both large- and small-seeded cultivars. However, with small-seeded cultivars the yield was not significantly influenced by differences in plant stand. When the large-seeded cultivar was broadcasted and mulched, yield was higher than with other treatments. Under no-tillage rice-stubble cultural conditions, spaced sowing and drilling were best for good plant stand and high yield. In the autumn season, spaced sowing and drilling the seeds gave significantly higher plant stand than the other methods in both small- and large-seeded cultivars under tilled field conditions. In no-tillage fields, broadcasting double the seed rate with normal or presoaked seed, plus mulching with rice-straw, gave better plant stand than the other treatments. Excess moisture soon after sowing was harmful for germination in drilled and spaced sowing treatments in tilled fields. Under such conditions broadcasting the seed and covering it well or mulching with rice-straw was beneficial. In the dry season, providing adequate moisture appeared to be a limiting factor. Spaced sowing and drilling the seeds appeared best for good plant stand in tilled fields where irrigation was more even. Our results suggest that the appropriate sowing method depends on moisture control, season, seed size, and land preparation. Spaced sowing or drilling the seed is a relatively risk-free way of getting good plant stand and optimum yield under certain conditions. If the broadcast method of sowing is adopted, seed rate needs to be increased, seed should be covered properly, mulching should be done, and moisture control is essential for good plant stand and optimum yield.

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Some Aspects of Soybean Production and the Quality of Soybean Seeds in Heilongjiang Province

Lian Zheng Wang

Heilongjiang Province is one of the main areas of soybean production in the People's Republic of China. It ranks first both in area and in total output of all the provinces. The average output per ha is 1.5 ton. In 1979 the soybean area in Heilongjiang occupied 1,660,000 ha, but by 1985 it will be 2,000,000 ha. The yield per unit area in soybeans was raised during those years mainly by using improved cultivars, selecting good seed, and increasing the use of fertilizer, as well as by improving field management and working to prevent damage from harmful insects. In order to raise soybean seed quality, the province has formulated a criterion for grading seeds, so grades of elite seeds and breeders' seeds have been determined. In harvesting, the number of broken seeds should be minimized for good cultivar propagation. Harvesting is usually done by Dongfeng combines on state farms but by manual labor in the people's communes. After harvesting, seed is stored at room temperature. The lowest storage temperature may be 30° to 35° C below zero. Moisture contained in the seed is about 13 percent, so the germination percentage of the seed is not lowered by the low storage temperature. Seed cleaning is usually done by spiral type seed-sorting tool apparatus, which sorts out broken seeds and seeds damaged by pod borers. The most fertile land should be chosen for growing good cultivars. The germinating rate of sown seeds should be above 95 percent, and the amount of seeding per ha usually 75 kg. It is necessary to use Trifluralin for weed control. During growth period the soybean should be protected against pod borers by the use of DDVP.

DISCUSSION

S. Shanmugasundaram: Professor Wang has discussed soybeans from the point of view of rainy and dry seasons. The developing countries may consider growing vegetable soybeans during the rainy season. If it is done then, there is no need to worry about seed quality. However, seed for soybeans should be produced elsewhere.

China, Indonesia, and Thailand are the major soybean producers in Asia. How is the soybean seed stored and distributed in those countries? Is there anyone here from Indonesia?

C.L. Wang: I think Dr. Shanmugasundaram's idea is correct and valuable. The mode of production and use of soybeans should be adaptable to the conditions of a particular country or locality.

P.R. Hepperly: In work at Illinois (a temperate climate), intercropping of soybeans and maize did not yield as high as a single crop of corn, but in work at Puerto Rico (a tropical climate) intercropping resulted in an increased yield. Does the same situation occur in North and South China?

C.L. Wang: In the Northeast of China, the intercropping of soybean and corn is mainly for raising the yield of corn by letting the tall corn have more light. In the South, soybeans are usually planted later and mature later than corn, so after the corn harvest, both a growing period and space are left for soybeans. The total amount of production of corn and soybeans will be higher, and the hazards of production will also be reduced, to a certain degree.

A.R. Khan: Do you use any *Rhizobium* strain for the purpose of inoculation?

C.L. Wang: In commercial production we rarely use *Rhizobium* except for newly cultivated land where soybeans are to be planted for the first time.

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J. Joshi: Since soybeans are used as food in China, how do you manage to take out the trypsin inhibitor and other antinutritional factors?

C.L. Wang: We do this only by boiling or roasting at high temperatures. In China both soybean food and feed are heat-treated. We don't eat fresh soybeans, even the fresh vegetable beans. (In a few cases people eat the fresh green beans.)

M.D. Tedia: Why is the average yield in Northeast China 3,000 kg/ha as compared to the South, where it is 1,000 kg/ha?

What is the cause of this wide difference in yield?

C.L. Wang: In the Northeast of China, there are large areas (100-200 ha) of field blocks of soybeans with yields as high as 300 mt/ha, but the average yield of the whole Northeast is only 1 to 6 mt/ha. The reason that soybean production in the South is low is that soybeans are planted after winter wheat or spring rice, so that the seeding time is very late, and such soybeans grow under short day conditions. Another reason is that soil in the Northeast is richer than that in the South.

A. Sajjapongse: What herbicide do you use for controlling weeds in soybeans, and what are the major weeds?

Also, how often do you irrigate soybeans during winter planting in the southern part of China?

C.L. Wang: The herbicides we use on the state farm for weed control are Trifluralin and Lasso. Most herbicides are imported, but Chinese-made 2.4-D is also used. The major weeds in the Northeast are smartweed, cockleburs, wild morning glory, foxtail grass, and pigweed. As to irrigation, in the Middle South of China where autumn soybeans are cultivated, soybeans are irrigated 2-3 times during blooming and early podding time. In the South, where winter soybeans grow during the dry season, farmers irrigate soybeans once every 6-7 days.

Degradation of Quality in Soybean Seeds by Exposure to High Temperature

S.H. West

Often soybean seed quality is lost due to on-the-farm storage both before plantin and during the planting procedure, because of high temperatures. High temperatures have been recorded in the top bags of seed in a stack in storage under a metal roof and in bags receiving the direct noonday sun. Tests were conducted to determine soybean seed tolerance to 55° C. Bragg soybean seeds at 12 percent moisture were subjected to 55° C for periods from 30 minutes to 24 hours. After exposure to the temperature treatments, the seeds were germinated and tested for quality deterioration by accelerated aging and emergence procedures. After 24 hours, total germination was reduced from 95 to 75 percent by the temperature treatment, whereas "normal" germination was reduced from 70 to 30 percent. Emergence from the soil after 8 days was reduced from 80 percent with no temperature treatment to 45 percent by the 24-hour exposure. In the aging test, total germination was reduced from 70 percent with no treatment to 50 percent after 6 hours and to 4 percent after 24 hours. After 6 hours of exposure to 55° C no "normal" seedlings were produced. Emergence of seedlings from seed subjected to accelerated aging was 40 percent when no temperature treatment was imposed, while after 12 hours of 55° C only 20 percent emerged. This experiment suggests that soybean seed vigor and, thus, stand establishment may be influenced by exposure to high temperature.

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Effect of Seeding Method and Density on Stand Establishment and Soybean Yield in Slimania, Morocco

M.A. Yacoubi

Seven different methods of seeding (five hand and two mechanical) were used along with five seeding densities (70, 80, 90, 100, and 120 kg/ha) of Clark 63 (in 1978) and Calland (in 1979). These soybean cultivars were tried in a field located in the northeast corner of Morocco, near Oujda, on the 22nd of May in both 1978 and 1979. The light sandy-loam soil received 25-60-30 fertilization. All the seeds were inoculated, in 1978, with imported Nitrogin at the rate of 10 gm/kg of seed. The treatments were replicated four times and placed in a completely randomized block design. The areas of the elementary plots varied from 32 to 85 m^2; however, an equal, centrally located unit area was harvested and the yield weighed for purposes of statistical analysis.

In 1978, the stands varied from an equivalent of 250,000/ha to 321,200/ha and the yields were located between 3.78 mt/ha and 4.95 mt/ha. The best stand and yield were obtained in the treatment where seeding was on top of the ridge (row) at 5 cm x 50 cm spacing. The differences within the same seeding rate were not statistically significant at the 1 percent level (F test). The highest yield and stand were in the 90 kg/ha treatment.

In 1979, 350 kg of N were added in lieu of inoculation. The stands varied from 267,000/ha to 406,300/ha and the yields were as high as 4.75 mt/ha and as low as 3.53 mt/ha for the average of four replications. The individual values were between 1.75 and 5.65 mt/ha. The best stands were obtained for the Nodet solid seeding, while the best yield was obtained for the seeding in the water line (approximately at one-half the ridge) with 5 cm x 50 cm spacing. At the rate of 80 kg/ha, there was a significant difference (5 percent level) in favor of the water line seeding vs. the top of the ridge seeding.

In both years there was a poor correlation between stand establishment and yields ($0.384r^2$). The depth of seeding could not be adequately controlled for the seeding done at the water line by hand. This lack resulted in some cases in a lower germination percentage.

Further trials need to be carried out before we can advise the farmer adequately on his seeding methods. Meanwhile, water line seeding seems to be the most promising when the depth of seeding is adequately controlled (for example, using mechanical/calibrated tools).

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Report of the Working Committees

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Production

CHAIRMAN, H. M. E. HERATH
RECORDER, H. C. MINOR

The committee addressed the problems of seed quality and examined major areas of concern, for which recommendations were made.

An important attribute of soybean seed is its ability to store well. Cultivars which produce seed lacking the ability to survive from one planting season to the next are of limited long-term usefulness. Techniques now available for the evaluation of storage potential can be applied as standard practice in field trials. Therefore, it was recommended that national soybean research programs make the improvement of seed storability a major priority, and that genotypes in national and international yield trials be characterized for their storability under ambient conditions in the respective countries. Results should then be given to a coordinator for compilation and dissemination.

It was further recommended that E.A. Kueneman of IITA undertake to prepare instructions for a standardized evaluation of soybean seed storability, furnish identified sources of improved storability, assemble information as it becomes available from cooperating programs throughout the tropics, and distribute that information to interested parties. Such an effort would provide basic guidelines to numerous programs for the evaluation of soybean genotypes with respect to this important characteristic, and thus lead to the rapid selection of genotypes with improved storability and production practices that result in seeds with improved storage characteristics.

Further discussion led to suggestions that a soybean seed quality newsletter would be useful. It was suggested that INTSOY, or a similarly interested international program, consider the publication of such a specialized newsletter. Current forums for information on seed quality include IITA's Tropical Grain Legume Bulletin and the Soybean Genetics Newsletter.

The observation was made that unnodulated soybeans grown without adequate nitrogen produce seeds of poor quality. Questions were raised about the production of an adequate supply of high quality inoculum for soybeans with regard to quality control, effective carriers, mass production technology, the survival of strains in various tropical soils, and the effectiveness of indigenous strains. It was suggested that the development of soybeans compatible with a wide range of native *Rhizobium* strains might help eliminate problems related to N-fixation, as in the case of Zambia, where selected soybean cultivars were infected in such a way.

Therefore, it was recommended that quality inoculum or N fertilization be used in seed-production fields. In general, effective inoculation is required for the economic production of good quality seed. NIFTAL should be looked to for guidance.

Subsequent discussion included other adverse soil conditions. It was further recommended that all fertility conditions that result in growth stress during the production of quality seed be ameliorated.

The committee also considered the effects of multiple cropping systems on seed quality, as follows:

1. Storage time can be affected. The inclusion of soybeans in the cropping system throughout the year provides a mechanism to ensure a continuous supply of fresh seed. This technique for seed production is used in some areas but has not been exploited in others where it might have potential.

2. Stand establishment can be affected. An existing crop may provide protection from elements detrimental to the maintenance of a good seed bed. Direct impact of raindrops may be avoided, thereby reducing the potential for crust formation.

3. Seed quality can be directly affected. (Specific effects were not mentioned.) How shading may affect seed quality in a multiple cropping system can only be guessed at, since most effects of cropping systems on seed quality are speculative. It was recommended that the potential effects of a cropping system be investigated, particularly management practices that improve the emergence of seeds from the soil.

In the case of the primary physiological changes in seeds that result in loss of vigor, additional clarification is needed. Seed pigments appear to be involved in protection, but the relationship is unclear. The role of antioxidants in seed longevity should be determined. It was therefore recommended that some funding institution be approached to support basic research in these areas.

The committee addressed the evaluation of seed quality (specifically, measurement of germination) that precedes the actual planting operation to such an extent that it often provides no meaningful measure of the quality of those seeds finally placed in the soil. To assess the status of the seed as it goes into the ground, it was recommended that planter box surveys be made a part of production efforts. For commercially produced seed, these surveys would provide an estimate of the total deterioration in seed quality that occurs during storage, during transport, and during the holding period on the farm just prior to planting.

Finally, the committee considered the exchange of germplasm that accelerates improvement efforts. Free exchange is frequently hampered because of questions related to the presence of seedborne pathogens. There is a need for one or more international centers for the multiplication and distribution of disease-free seed. National programs often lack the staff and facilities to handle efficiently the numbers and quantities of genetic materials needed. It was recommended that FAO be approached to assist in the organization of centers for this purpose.

Crop Protection

CHAIRMAN, F. C. QUEBRAL
RECORDER, P. R. HEPPERLY

The committee first considered the problem of insect pests that represent a serious constraint to soybean quality and stand in Asia. They are (in order of degree of harmfulness) bean flies, stinkbugs, leafhoppers, pod borers, and storage insects.

Research on the bean fly has been limited. There has been a lack of behavioral studies in "wet" seasons and studies on possible biological control, and information on the effect of cropping systems on bean-fly development is limited. Sampling methods have not always been reliable. Most important of all, perhaps, has been the dearth of cultivars that are resistant to the bean fly.

It was recommended that a team of entomologists, agronomists, and breeders be formed to organize a network to identify and screen soybean lines for increased resistance. Regional trials and surveys were also recommended to determine the occurrence and severity of bean flies and to suggest important environmental or management factors in the field affecting bean-fly development. It was suggested that a conference of Asian workers be planned to stimulate closer coordination of research activities.

Stinkbugs represent another major hazard to the crop in Asia. There is insufficient knowledge about them, as well as insufficient understanding of the interactions of fungi, bacteria, and other insects with them. Again, there is a dearth of cultivars resistant to stinkbugs.

The committee recommended further investigation of host preference of this pest, and the mapping of host plants to learn which areas are prone to infestation. The interaction of environmental factors with population development of the insect needs to be studied. The role of microorganisms in stinkbug damage should be clarified, since work in this area has yielded conflicting results.

The leafhopper represents another spoiler of Asian soybeans. Again, Asian information about such damage is limited; there has been little investigation into the possible effects of leafhopper activity on seed quality. The committee recommended that considerable effort be placed on predictions of insect populations in relation to crop developmental stages, management factors, and prevailing weather patterns. Thus, yield loss determinations could be related to predictions of insect population levels, if influencing factors like weather and crop management were also taken into account.

With pod borers, too, the committee found a lack of information about host plant preference and the characterization of environments favorable to damage development. Little work has been done on improvement of existing biological and chemical controls and their possible integration. Much work remains to be done on the identification and use of soybean lines resistant to pod borers.

It was recommended that planting calendars be developed for specific production areas in which pod borers develop seasonally. Economic thresholds for implementing chemical or other controls should be determined.

In considering storage insects, the committee found a lack of screening of soybean lines for resistance, as well as insufficient identification of biological principles affecting resistance to such insects as *Saponia*. Few studies have been done on how grain susceptibility is influenced by storage time, conditions of storage, and conditions of stored seed.

The committee suggested studies on control of storage insects with substances that are relatively cheap and available, such as talcum powders, bentonite clays, wood ashes, and vegetable oils.

In analyzing the problems of Asian soybean pathology, the committee felt a major area of concern to be the limited knowledge of conditions that result in seed transmissions in seeds infected by seedborne fungi, bacteria, and viruses. Economic threshold levels and well-documented seed thresholds are lacking for various pathogenic fungi, bacteria, and viruses. There is insufficient surveillance and monitoring of the geographical distribution and severity of soybean diseases throughout Asia, as well as a dearth of adequate seed testing and more reliable seed-health procedures. Finally, Asia suffers from a scarcity of chemical and physical aids to help prevent mechanized damage at harvest, to aid in processing, and to repel the invasion of seed by microorganisms during storage.

To remedy these problems, the committee suggested that studies of seed transmission and epidemiology be emphasized, aimed at the development of an economic threshold for seed infections. Techniques should be sought to detect diseased plants and seeds without destructive samplings. Such techniques should help eliminate infected plants and seeds by rogueing or seed separation. In extension courses, continued emphasis should be placed on the need to shift seed production to drier, cooler areas and to minor seasons in order to minimize disease hazards.

Finally, the committee suggested an Asian-African conference, to determine certification standards and oversee the testing of soybeans produced in the tropics and subtropics.

Storage and Mechanization

CHAIRMAN, PETCHARAT WANNAPEE

RECORDER, B. R. GREGG

The committee addressed itself to the problems of soybean seed from harvest through storage. Constraints were considered and the overall situation was assessed.

It was observed that tropical climates tend to be inimical to the storage of soybean seeds, which lose viability rapidly in storage. Farmers in these climates tend to be inexperienced in the matter of soybean storage, and there is a serious lack of adequate drying and storage facilities on most farms. No reliable information is available on safe storage temperatures for seed of different moisture contents and for different storage periods.

There is a serious shortage of precise, practical research data for almost all aspects (under tropical conditions) from harvest stages and methods through drying, as well as storage moisture contents and conditions, and even packaging. Although many operations in grain production can be done in one way, seed production sometimes requires the operations to be done in a different way; nevertheless, seed is still being produced by grain production techniques.

Drying is a major problem, and is affected by factors as diverse as planting date, harvest, and handling methods. Little information exists as to the safest practical methods under different conditions. Farmers lack methods by which to determine when seeds have been adequately dried, or when moisture content is safe.

Farmers also suffer since present seed programs incur high costs in providing quality seed to them. No complete technology system exists which might reduce the cost of seed to farmers. Existing seed quality control mechanisms are inadequate; they should begin before the seed goes into the bag and follow the seed until it is planted.

Perhaps most unfortunate of all, the committee agreed, is that the research data that are available are not being adequately used in practical seed operations. The data have never been collated into a continuous system.

To alleviate the situation, the committee considered and made a number of recommendations.

It is imperative that the drying problem be addressed. Existing information on harvest, drying, and storage should be compiled into detailed, practical manuals to guide seed producers in every step of the required operations. Recommended procedures should span planting dates, harvest, on-farm handling, and every aspect of drying and storage, specifically for seed.

Complete, detailed plans for storage systems and operations for seed should be prepared, perhaps as different models, for both on-farm and volume soybean seed storage. Construction plans must be designed for different sizes of storage, different construction materials, and widely varying conditions. A distinction must be kept in mind between farm storage and storage in seed programs; each requires distinct operations, technologies, and conditions.

A separate production technology should be prepared in detail for seed crops, to be a complete package of practices, a technology for seed production. Each country should study its crop production areas to identify those areas and conditions best adapted to seed production. Various storage and drying methods (such as moisture contents, packaging materials, and farmer storage periods) should be field-tested in selected areas of each soybean-producing country with tropical conditions. Information on moisture-testing methods suitable for farm use (such as strips impregnated with lithium chloride or portable moisture testers) should be disseminated to farmers who produce soybeans and soybean seed.

Identification should be made of air-conditioning and dehumidifying equipment available and suitable for different storage uses, and this information should be made generally available, along with information on sources, operation, and spare parts. Suitable back-up equipment should be prescribed for each type of conditioned storage. Special designs and other recommendations should be prepared for conditioned storage where electricity supply is a problem. Comprehensive research should be addressed to sealed storage, energy conservation, and solar dryers under tropical conditions. A simple means should be devised for isolated seed-program personnel to identify storable and nonstorable lots.

Breeders should be encouraged to develop good agronomic cultivars with improved seed storability. All known small-farmer drying methods and systems should be collected in each country and tested in a regional agency to develop recommended procedures that would become standard.

Designs of all small farmer threshers used for soybeans should be collected from each country. These threshers should be tested by a central agency or several agencies, and specific recommendations made for threshing soybeans under different regional conditions. A complete mechanized system or at least an improved level of mechanization for the small farmer should be developed. It should focus on helping the farmer with little investment capital to get his crop out of the field and into safe storage faster.

Inexpensive seed-cleaning methods should be tested and recommended for use by different levels of small farmers and for village cooperatives or farmers' groups, to improve the purity of their seed. More precise intervals and stages of testing seed during storage, before processing, and during distribution should be determined in order to avoid deteriorated seed being delivered to the farmer. More standardized quality testing methods and procedures should be developed, and quality control personnel should do the test work. Seed-program personnel should be thoroughly trained in the systems, methods, and procedures developed through research so that they can efficiently assist seed-producing farmers.

Perhaps most important of all, the committee emphasized that immediate and coordinated research be initiated to overcome the serious lack of precise, practical data on all the aspects of seed harvest, drying, and storage for volume seed production under tropical conditions. Such research is urgently needed to provide more information on almost every detail of these operations.

It may be that those who work to solve the problems of the soil bear a special responsibility. Only by sharing their knowledge and working together to overcome deprivation and isolation can the ancient specter of hunger be vanquished.