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9. ABSTRACT
An extensive evaluation of various varieties of soybeans was conducted to identify the varieties with the best potential for home and commercial production in the less-developed countries of the tropics and subtropics. Some 90 countries volunteered to participate in the program. Seed from promising varieties was increased in Puerto Rico and then distributed for use in preliminary observation trials at selected locations in six countries.

In plant protection work, a pest management program developed for use in Illinois was tested in Brazil with encouraging results. Studies of economic injury levels and host plant resistance were conducted, as were virus vector studies on soybean mosaic virus and tobacco ring-spot virus. Various seedborne microorganisms and pathogens associated with soybeans in selected countries were identified.

Research in soybean food use led to development of concepts for rapid preparation of weaning foods and soybean-cereal patties, a procedure for preparing a soybean beverage for village use, and appropriate methods for home and village-level preparation of the foods and beverage. A study was made of the effects of using corn, rice, or wheat flour as ingredients in drum-dried soy-cereal weaning foods. Also studied were water uptake and use of sodium and amonium bicarbonate for their effects on tenderness of cooked soybeans. Protein efficiency ratios were determined on many prototype foods made wholly or partly from field varieties of soybeans.

The research results were disseminated through an active publication series, a newsletter, regional workshops, training courses, and country programs. The soybean development network was expanded through formal linkages between INTSOY

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and national and international organizations.

DEVELOPMENT OF IMPROVED VARIETIES OF SOYBEANS

Final Report on
Contract AID/CM/ta-c-73-19
April 1, 1973 to March 31, 1976

Submitted to
The U.S. Agency for International Development
Department of State
Washington, D.C.

by
The University of Illinois at Urbana-Champaign
College of Agriculture
International Soybean Program, INTSOY

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REPORT SUMMARY

A. Statistical Summary

1. Project Title and Contract Number: Development of Improved Varieties of Soybeans - AID/CM/ta-c-73-19.

2. Principal Investigator, Contractor, and mailing address: William N. Thompson, Director, International Soybean Program INTSOY, College of Agriculture, University of Illinois at Urbana-Champaign, 113 Mumford Hall, Urbana, Illinois 61801.

3. Contract Period: April 1, 1973-March 31, 1976.

4. Period Covered by Report: April 1, 1973-March 31, 1976.

5. Total AID funding of contract to date: $980,605.

6. Total expenditures and obligations through previous contract year: $457,745.

7. Total expenditures and obligations for current year: $533,545.

B. Narrative Summary of Accomplishments

An extensive program in soybean variety evaluation was conducted to acquire information on soybean varieties having potential for home and commercial production in the less-developed countries of the tropics and subtropics. By the third year of contract operations, 90 countries had volunteered to participate in the program. Seed from varieties exhibiting promising production characteristics was increased in Puerto Rico and was distributed during the last quarter of the contract for use in preliminary observation trials at selected locations in six countries.

Plant protection work was characterized by extremely close working relationships among the soybean breeding group, plant pathologists, entomologists, and agricultural engineers. A pest management program developed for use in Illinois was tested in Brasil with encouraging results. Studies of economic injury levels and host plant resistance were conducted. Virus vector studies on soybean mosaic virus and tobacco ring-spot virus were conducted by a two-man team from entomology and pathology. Various seedborne microorganisms and pathogens associated with soybeans in selected countries were identified. Investigations were made on the pathogenicity of various isolated organisms and their role in reducing germination in emergence of soybean seedlings. A study was made of the sites of primary infection by various pathogens in the soybean seed.

Research in soybean food use led to development of concepts for rapid preparation of weaning foods and soybean-cereal patties, a procedure for preparation of a soybean beverage for village use and the appropriate technologies for home and village level preparation of the foods and beverage. A study was made on the effects of using corn, rice or wheat flour as

ingredients in drum dried soy-cereal weaning foods. Investigations were carried out on water uptake and use of sodium and amonium bicarbonate and their effect/relationship to tenderness of cooked soybeans. Protein efficiency ratios were determined on many prototype foods made wholly or partly from field varieties of soybeans.

Dissemination of research results was accelerated through an active publication series, a newsletter, regional workshops, training courses, and country programs. The soybean development network was expanded through formal linkages between INTSOY and national and international organizations and with a host of individuals and institutions who share INTSOY's interest "to expand the use of soybeans for human food."

FINAL RESEARCH REPORT

A. General Background

Contract-sponsored research constitutes a major component of the work of the International Soybean Program, INTSOY. It provides a firm base from which education, training and service activities can proceed. Research contract staff have participated, and continue to participate, in these activities to minimize the time of acceptance and use of research results. In addition to its primary emphasis on reporting research activities, this report will relate a number of interactive and complementary endeavors to give the reader a broader, but more accurate, picture of the importance of sponsored research as the "glue" that holds the INTSOY program together.

The soybean has received increased attention in the past few years for its potential as a major food crop, especially in developing countries of the tropics and subtropics. Soybeans have important advantages among alternative cropping choices in attempting to alleviate world food shortages and to improve the diets of under- and malnourished people. The soybean produces the highest yield of protein per unit of land area of any plant or animal food source while at the same time producing calories. It contains about 40 percent protein and about 20 percent fat. The amino acid distribution of soybean protein approximates that recommended by FAO for maximum protein utilization. The soybean also has the ability to provide its own nitrogen requirement through symbiotic nitrogen fixing bacteria, Rhizobia, and to leave a generous amount of nitrogen in the soil for a subsequent crop. This itself is a key factor in a period of rising fertilizer prices and becomes a major consideration in the development of cropping systems keyed to limited inputs of fertilizers and other chemical agents.

While soybeans are currently widely used directly as human food only in Asia, the basic processes for conversion of whole soybeans to human foods are known. Still, intensive adaptive research, process development and nutritional studies are needed to provide the information necessary to encourage widespread acceptance of soybeans in the diets of low-income people. It is only through a concerted attack on the problems of soybean production and use that the nutritional potential of soybeans can be realized on a worldwide scale. This fact is clearly understood by the Agency for International Development and it has provided for additional research funds to carry on the necessary work effective April 1, 1976.

B. Project Objectives as Stated in the Contract

The general objective of the project, as stated in the contract, is to "perform a research and development program directed toward the development of improved varieties of soybeans." The objective is elaborated upon in the specific statement of work that provides that the contractor will undertake:

1. Development of technical assistance and research linkages in tropical soybean variety improvement, cultural practices, inoculation, pest control, and harvesting, processing and storage methods;

2. Research to screen the soybean for broad adaptation to the tropical soils, tropical climates, and insect and disease resistance;

3. Research on isolating and testing Rhizobium strains where their effect on fixing nitrogen and increasing yields;

4. Assistance in backstopping LDC institutions in conducting cooperative adaptive research in soybean improvement;

5. Programs of formal and practically oriented training and guidance in soybean research;

6. Demonstration in selected countries of Latin America, Africa, and the Far East of the University of Illinois process for rapidly rendering soybeans available in the village and at the home level as a human food in an effort to determine what regional modification the process may require in order to make the product acceptable to the local pallet and usable in soy-based foods; and

7. To make available improved soybean varieties and products to LDCs and cooperating research institutions for trial under the individual conditions of the developing countries.

C. Continued Relevance of Objectives

Events over the three-year life of the research contract, and experiences gained from them, confirm three major assumptions:

1. That the general problem addressed is of critical importance;

2. That there are constraints to production and use of soybeans that can be reduced only through a combination of basic and adaptive research; and

3. That there is a widespread interest among governments and scientists in cooperating countries in participation in research and development activities.

Notwithstanding the validity of the general project objectives, serious constraints of time and funding combined to work against the full realization of those objectives. The constraints were recognized early in the project and were addressed at that time. Concentration of effort focused on soybean variety development, soybean entomology and pathology research with emphases that complement variety development research, and evaluation of varieties for nutritional values and cooking qualities. Funding was inadequate to conduct research on all aspects of production and on marketing and storage.

Three specific areas of research that could not be adequately performed with available resources were omitted. They were:

1. Development of technical assistance and research linkages in cultural practices, inoculation, harvesting, processing, and storage methods (parts of objective 1).

2. Research on isolating and testing Rhizobium strains for their effect on fixing nitrogen and increasing yields (objective 3).

3. Demonstrations of the University of Illinois soybean processing methods (part of objective 6).

Subsequently, work plans were carefully redrawn to concentrate on activities that could be adequately funded and staffed under the project. Significant additions were made to the contract staff in the area of plant protection (insects and diseases). An associate director, stationed at the University of Puerto Rico Mayaguez Campus, was added on a one-quarter time basis to strengthen program coordination in planning, administration, and operation. Work focused on soybean variety development, information systems, insect collections, insect pest management, soybean pathology, evaluation of cooking and nutritional qualities, and home and village level processing methods.

D. Accomplishments

The results of the research reported for the three-year project period may be considered from two perspectives. The first is concerned with the findings of individual researchers or teams of researchers in the subject-matter areas. The second deals with the interdepartmental, interinstitutional collaborative methods used by project staff to conduct contract research. This inter- and multidisciplinary approach has been a highly successful feature of the INTSOY program, not only in the conduct of research, but as a demonstration to cooperating country scientists of a systems approach to the problem of improving protein-calorie intake in the diets of the rural poor.

While the research findings and their significance reported below will be made in subject-matter terms, the reader will be continually aware of inter- and multidisciplinary cooperation, and of intra- and interinstitutional cooperation. The capacity for a research project such as this to promote and stimulate problem-solving research among and between scientists, subject-matter areas and institutions is perhaps one of its greatest by-products.

1. Soybean Variety Development. The major objectives of variety development are high yield and high protein per unit of land area, suitable photoperiod response, resistance to limiting diseases and insect pests and wide adaptability in tropical and subtropical environments. The primary thrust in the soybean variety development work has been through the International Soybean Evaluation Experiment (ISVEX). This comprehensive variety testing program in which collaboration is by voluntary association, has grown from 33 countries and 90 locations in the first year of the research contract to 90 countries and 257 locations at the completion of the contract. In this experiment, a standard variety trial is grown at each location and data are collected and returned to the trial coordinator at Urbana-Champaign for analysis. Initially, the trial included 20 varieties in U.S. maturity groups I through IX. During the second year, the number of varieties was reduced from 20 to 15 including the 12 best performing varieties in ISVEX 1. Some cooperating LDCs desired short-season soybean varieties to fit local environmental conditions or cropping systems. In response to these demands,

two sets of varieties were established, an early set of varieties from U.S. maturity groups 00 through group V and a later maturity set of varieties from U.S. maturity groups III through IX. Cooperators provided the land, labor, fertilizer and management necessary for the experiment. Instructions for management and data collection were sent to each cooperator to standardize method among sites. General information about the site and the experiment was returned to INTSOY including details of latitude, elevation, and soil conditions of the site plus date of planting and harvesting, amount of moisture, fertilizer used, local varieties tested and diseases and insects of the environment. Data reported for each plot by cooperators included yield, seed weight, days to flower, days to maturity, canopy height at flower, plant height at maturity and estimates of lodging and shattering. Seed samples were also returned to INTSOY for protein and oil content analysis.

The results of the first ISVEX has been published as Number 8 in the INTSOY Publication Series. Data for the second ISVEX is under analysis and the results will be published later in 1976. The preliminary analysis of data is found in Appendix I-A.

Data are being received from the third ISVEX conducted during 1975. To date, information has been received from 61 sites in 36 countries which tested ISVEX 3. ISVEX 4 is now under distribution. Six sets of cultivars, organized by environmental zones utilizing cultivars which have performed well in past experiments and new entries with potential in each environment, are being distributed in ISVEX 4 during 1976. By the end of the research contract, ISVEX 4 had been requested by 181 sites in 50 countries and additional requests were being received regularly.

The high grain yield achieved in experimental plots with good management indicates that soybeans do have production potential in many new areas of the world. Temperate environment cultivars do not produce ideal plant types when grown in the tropics but extensive breeding programs can improve these characteristics. The ISVEX has provided answers to some questions about the adaptability of temperate zone cultivars in the tropics and questions relating to seed quality and growth at high altitudes are being addressed in ISVEX 4.

Commencing in 1976 new material will be moved from the increase program in Puerto Rico to identified potential areas of adaptation. The Soybean Preliminary Observation Trial (SPOT) has been designed to serve as a screening test for new material. In 1976 the SPOT is being conducted at six sites which represent environments where the ISVEX has been grown successfully. SPOT 1 includes 14 cultivars representing material from five countries, and range from small seeded types to a large seeded vegetable type. During 1976, SPOT 1 will be tested in Ecuador, India, the Philippines, Puerto Rico, Rhodesia, and Sri Lanka.

Joint experiments have been organized with the International Institute of Tropical Agriculture (IITA) and the Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA) to eliminate duplication of testing the same material at the same research stations. Other organizations which have requested ISVEX include the Food and Agriculture

Organization of the United Nations (FAO) for testing by their staff in 12 countries. The French Institut de Recherches Agronomiques Tropicales et des Cultures Vivrieres (IRAT) for testing in 11 countries, and the South Pacific Commission for testing in five countries.

Two other studies in variety development illustrate the complementarity of work between the research contract and the INTSOY 211(d) Grant AID/CM/ta-g-73-49. The effects of storage conditions and environment during maturation on soybean seed quality and crop performance were studied by a doctoral candidate from India over a 2 1/2-year period. The Ph.D. dissertation has been completed and articles are being prepared for publication. The summary of the student's seed quality studies is provided in Appendix I-B.

Another student conducted field screening experiments for daylight sensitivity for accessions from U.S. maturity group III in Puerto Rico. Of the 515 genotypes screened one line, PI 317.334b (Kitami Shiro) was identified as possessing unique photoperiod insensitive properties which will be useful in the breeding of soybean lines with wide latitudinal adaptation. This research is helping to determine relationships among flowering, maturity and photosensitivity of soybean genotypes. A Ph.D. dissertation will be completed by late summer, 1976. A summary of the work on the screening for daylight sensitivity may be found in Appendix I-C.

2. Taxonomic Information Retrieval System (TAXIR). TAXIR is a system for coding germplasm information published in USDA/ARS regional soybean laboratories manuals on punch cards for quick retrieval. Information derived from the ISVEX and from the breeding program conducted under the 211(d) grant in Puerto Rico is coded and integrated into the system. Information which is entered concerns five sources of soybean germplasm: (1) named soybean varieties; (2) type collection lines; (3) species collections; (4) plant introduction; and (5) forage collections. By the end of the report period, over 3,700 entries had been integrated into the TAXIR system. The number of possible characters recorded for each entry had been increased to 172. Work was completed on a publication on morphological descriptions and responses to foliar, stem and root diseases of U.S. and Canadian soybean cultivars and it was produced and distributed as Number 9 in the INTSOY Publication Series.

3. Insect Control and Entomological Studies. The objective of the entomology research program is to devise control strategies that encourage economically high yields and to aid research scientists involved in solving soybean-insect problems. Since the inception of the research contract, attention has been given to providing soybean scientists worldwide with information on insects affecting soybeans and collecting, processing, and identifying soybean arthropods. With partial support from the research contract, the Illinois State Natural History Survey and other sources, these service oriented activities have proven to be a valuable resource to soybean research workers around the world. The Soybean Insect Research Information Center (SIRIC) has increased its capacity by about one-third through support from the research contract. The information center contains over 13,000 titles covering literature of insects associated with soybeans and insect borne diseases of soybeans. Bibliographic references are stored on magnetic tapes using FORTRAN IV language for retrieval on IBM 360-75. Programs

related to this computerized storage include routine checking of input data, updating of current data, entire or partial listing of the documents, and most importantly, searching of literature according to specific parameters.

Users of SIRIC are frequently impressed with its large number of foreign citations retrieved. SIRIC maintains close working relationships with researchers abroad and, as a result of this cooperation, it receives copies of articles published in soybean-producing countries. These articles are often published in foreign journals not frequently located in U.S. libraries. This places SIRIC as a valuable depository of foreign material.

Exhaustive searches have been made on some species of key importance. As a consequence bibliographies have been published on the Mexican bean beetle, Epilachna varivestis; Southern green stink bug, Nezara virivula; bean leaf beetles, Cerotoma trifurcata and C. ruficornis; velvet bean caterpillar, Anticarsia gemmatalis; Northern corn root worm, Diabrotica longicornis; and Western corn root worm, B. virgifera; and the spotted alfalfa aphid, Therioaphis maculata. Currently SIRIC is working on a bibliography of the Heliothis ssp. complex. Heliothis zea and Heliothis virescens are major pests of corn, cotton, tobacco, and soybeans and are considered the pests of greatest economic importance in the western hemisphere. SIRIC is also cooperating in compiling a bibliography on the pea aphid, Acyrthosiphon pisum (Harris) and the potato leaf hopper, Empoasca fabae (Harris), both of which are important to soybean entomology. Additionally, in depth searches on 24 species of important soybean insects is done on a routine basis.

The International Reference Collection of Soybean Arthropods (IRCSA) is a specialized resource base for researchers involved in many aspects of soybean protection. It serves as a depository, not only for specimens of soybean arthropods, but also for associated field data. It is exceedingly important to persons in institutions developing new soybean research programs as well as to researchers with well-established programs. With partial support of the research contract and the Illinois State Natural History Survey, IRCSA has increased its collection of specimens by approximately 100 percent, now numbering about 100,000. IRCSA has the capability of providing reliable identifications for 80 percent of North American soybean arthropods and 50 percent of South American species. As more specimens are determined by experts and placed in IRCSA, the number of reliable identifications possible by IRCSA staff will increase.

Linkages have been established with many U.S. institutions, national institutions from LDCs and international organizations. There have been increasing demands for IRCSA services by LDC institutions. The resource information contained in IRCSA has begun to be utilized by and incorporated into soybean insect pest management programs in other countries.

Additional information on both these valuable information systems can be found in Appendix II.

In 1974-75 impetus was given to the research aspects of the soybean entomology program with the appointment of pest management specialist. Working among and between disciplines the research contract supported pest management specialist has involved himself in a number of studies summarized below:

a. Rearing, sampling and mechanisms of observing movement of soybean insects (cooperative work with Dr. M. Kogan, Entomologist, Illinois Natural History Survey). Rearing methodologies were developed for the soybean Sericothrips variabilis and the bean leaf beetle, Cerotoma trifurcata. Sampling procedures were developed for aphids, thrips and most soybean pests under major predator spec. in North America. By extension, these methodologies will prove valuable on pests, vectors and natural enemies in other soybean-growing areas of the world. A marking system using RbCl translocated into plants and from them into insects was adapted to study both movement patterns of pests and trophic interaction in the soybean ecosystem.

b. Pest management systems (in cooperation with Dr. M. Kogan, Illinois Natural History Survey). A pilot pest management program was tested during the 1974-75 season in two locations in Brasil. The program was conducted in collaboration with scientists from Clemson University and two Brasilian institutions, the state-supported IAPAR in Parana and the industrial cooperative, FECOTRIGO, in Rio Grande do Sul. The program tested on large-scale commercial operations some of the assumptions of the Illinois Pest Management Program. In general, the program was a success at both Brasilian locations.

The pilot pest management program provided supported the basic premises on which the Illinois pest management program is based. The adopted economic damage threshold (combinations of population level plus defoliation level) although high did not pose any risks. No yield differences were recorded in the fields using the Illinois pest management guidelines versus fields receiving standard local farmer treatment practices. The timing, number of samples per field, and scouting procedures were adequate, although scouting time could be substantially reduced with better knowledge of the phenology of the pests. Incidence of the fungal diseases probably represent the single major mortality factor controlling populations of Lepidopterous caterpillars. Development of capability to present epyzootics as well as to promote epyzootics will represent a substantial advancement in soybean insect pest management. This program proved the feasibility of adapting simple scouting procedures to developing integrated pest management programs even if the knowledge of the phenology and population dynamics of key pests is not completely elucidated. Such programs can be adapted elsewhere as an interim procedure until more detailed information is gathered on the pecularities of the local pest complexes.

c. Economic injury levels (cooperative work with Dr. M. Kogan, Entomologist, Illinois Natural History Survey). Economic injury levels give vital information in a pest management program. They set limits of damage tolerable by soybean plants at different developmental stages of the plant to various pest species. Thus through scouting or supervision pest population can be monitored and damage level not allowed to exceed tolerable limits. Sufficient information is available from data developed

and economic injury level data of other researchers to give first approximations of damage thresholds for most defoliating soybean pests of the western hemisphere and for many of the eastern hemisphere.

d. Host plant resistance (cooperative work with Dr. M. Kogan, Entomologist, Illinois Natural History Survey). Over 1,000 breeding lines were planted in 1974-75 in cooperation with scientists from USDA Beltsville and Purdue University and tested for resistance, primarily to Mexican bean beetle. The breeding program continues under the coordination of Dr. R. L. Bernard, USDA Regional Soybean Laboratory, Urbana. Winter nurseries in southern Brasil were used in 1974-75. Marked differences in latitude resulted in inadequate growth of the Illinois lines. Selections made earlier by Dr. H. C. Minor from some of the original Illinois crosses resulted in late maturity group lines with considerable levels of resistance to the velvet bean caterpillar, Anticarsia Gemmatalis. Observations made in the Brasilian nurseries on selections made in South Carolina and Mississippi raise some critical questions about the use of these winter nurseries. Major problems include the expression of resistance under various adaphic and climatic conditions and the behavior of local pest populations of the same species that may differ in their genetic makeups (biological races). Germplasm from all of USDA's southern regional group VIII and IX has been evaluated for resistance to foliar attack by Cerotoma Ruficornis in Puerto Rico. All resistant material was found to be from group VIII.

e. Virus vector studies (cooperative work with INTSOY virologist, Dr. R. M. Goodman).
(1) Soybean mosaic virus. A study of the epidemiology of this virus was begun in February 1975 in Puerto Rico. Aphid abundance was never high and although seven species were collected from traps, only one, Tetraneura nigriabdominalis (Sasaki) was collected throughout the growing season in relatively high numbers. A second experiment was conducted in Urbana during the summer of 1975. Aphid movement and timing was monitored throughout the growing season. Results indicated that SMV did not spread more than two percent until early August at which time and within a single week spread soared to 80 percent of the plants in all plots including check plots. Although all the aphid data have not been analyzed those that have suggest that during the time of the explosive spread of SMV there was a correspondingly high proportion of Alate aphids. An extensive series of experiments on SMV epidemiology is planned for the summer of 1976.
(2) Tobacco ring-spot virus (TRSV). The vectors of this potentially important virus are not really known. Several arthropods (and a nematode) have been implicated. The major vectors probably belong to the Order Thysanoptera, the thrips. One of the most abundant insects of soybean fields in Illinois and throughout much of Latin America is the soybean thrips, Scricothrips variabilis (Beach). The determination of this insect as a potential vector of TRSV is of utmost importance to soybean growers in the U.S. and Latin America.

f. Bionomics of soybean insects (cooperation with Drs. M. Kogan and G. Waldbauer, Illinois Natural History Survey). Four sets of insects are under study, bean leaf beetles, Cerotoma spp., the soybean thrips Sericothrips variabilis, Orius insidiosus (a predator of Sericothrips variabilis), and Lepidopterous caterpillar parasitods.

g. Modeling for economic injury levels (in cooperation with W. G. Reusink and M. Kogan, Illinois Natural History Survey). A static model was proposed for economic injury level to soybean defoliators. Upon investigation of certain characteristics of the model, it became apparent that, although serving well with the first approximation, additional refinement was needed to reflect the dynamic nature of economic injury levels of defoliators. Dynamic models for populations of the bean leaf beetle, the green clover worm, and the alfalfa caterpillar were prepared based on existing data. The models revealed considerable gaps in basic biological information and stimulated the reassessment of research directions regarding those species. Data needed to improve the model and validate the results are being gathered.

Additional information on the research activities summarized above may be found in Appendix II.

4. Soybean Pathology. The objectives of the research effort in soybean pathology are: (1) to identify the limiting soybean diseases in the tropics and subtropics; (2) to generate basic information about soybean pathogens that can be used to predict their spread and importance; (3) to devise methods to control or reduce the impact of diseases; and (4) to assist in breeding tropically adapted soybean cultivars with resistance to important pathogens.

Soybean pathology work was integrated in the contract activities in the second year. Research was initiated in both fungal and bacterial diseases of soybeans and in virus diseases of soybeans. A considerable amount of work in both areas is conducted in cooperation with colleagues at the University of Puerto Rico Mayaguez and in cooperation with research in soybean variety development and in pest management.

Fungal and bacterial diseases of soybeans. Various seedborne micro-organisms and pathogens associated with soybeans from selected countries were identified. A bioassay of soybean seeds of 16 cultivars grown in Ethiopia in 1973-74 was made. Thirty-eight genera of fungi and bacterium Bacillus subtilis were associated with the various seedlots. A cooperative study between the soybean breeding-plant pathology program at the University of Puerto Rico-Mayaguez, is directed at finding those germplasm entries that show genetic resistance to internally seedborne micro-organisms. Samples from the world germplasm collection of maturity groups VIII, IX, and X have been bioassayed. More than 32 different genera of fungi have been identified. Two common bacteria observed were species of Bacillus and Xanthomonas. Studies were completed earlier on micro-organisms associated with soybean seeds grown in India. The Bacillus subtilis has been found to be associated with soybean seeds grown in Mainland China, Korea, Pakistan, Thailand, Ethiopia, Puerto Rico and the United States.

Investigations have been made on the pathogenicity of various isolated organisms and their role in reducing germination in emergence of soybean seedlings. One of the most important internally seedborne fungi associated with soybean seed in the U.S., Puerto Rico, and other countries is the Diaporthe phaseolorum var. Sojae (Phomopsis Sp.), a causal fungus of pod and stem blight disease. Seeds infected with this fungus rarely germinate although they may be viable prior to germination. It is one of the more important fungi contributing to the lowering of soybean seed quality. Seedlots of 12 soybean cultivars grown in northern, central or southern growing regions of Illinois were bioassayed for occurrence of seedborne micro-organisms and percentage of in vitro germination was recorded. Observations indicate there were significant differences in in vitro germination between but not within years. There were significant differences in occurrence of seedborne micro-organisms between and within regions and years. Significant differences in the occurrence of B phaseolorum var. sojae (phomopsis Sp.) was related to year and growing region, but not cultivar. There was cultivar interactions in in vitro germination, occurrence of total fungi and Bacillus subtilis regardless of growing region and year. The use of in vitro germination alone is not sufficient for determining seed health. The occurrence of seedborne micro-organisms must also be made.

Consideration was also given to a study of the sites of primary infection by various pathogens in the soybean seed. Most of the pathogens of soybean are seedborne. Soybean seeds become invaded by various micro-organisms that can reduce seed quality and viability before harvest. Some micro-organisms cause serious losses during the growing season. Seed infection also acts as a means of survival for many organisms. Some pathogens may remain viable longer than the seeds during storage. Seed infection may result in long-range dissemination of the pathogen resulting in introduction of primary inoculum into areas where the pathogen was previously absent. Seeds may become infected at any time during their development depending upon the pathogen involved.

In addition to the research summarized above, two major publications were made available in the past year. The first, "An Annotated Bibliography of Soybean Diseases 1882-1974," published as INTSOY Series No. 7 contains more than 2,250 citations. Publication of this bibliography is the first time that the world literature on soybean diseases has been brought together and annotated in a single volume. A companion book, "Compendium of Soybean Diseases," was published by the American Phytopathological Society. The Compendium gives consideracion to the world diseases of soybeans including nonparasitic diseases such as herbicide injury, air pollutants, temperature extremes and mineral deficiencies and toxicities.

Publication of the Annotated Bibliography was also supported by the Illinois Agricultural Experiment Station. Publication of the Compendium was co-sponsored by the American Phytopathological Society, the American Soybean Association, the Cooperative Extension Service, the Department of Plant Pathology, and Federal Extension Service.

Efforts were made to join in a cooperative effort with other pathologists for cooperative research on soybean rust. Under leadership of INTSOY scientists an international working group on soybean rust has been

formed. Dr. Charles Yang (AVRDC) is chairman. Dr. K. R. Bromfield (USDA/ARS) is vice-chairman and Mr. Shanmugasundaram (AVRDC) serves as secretary. The purpose of the international working group on soybean rust is to stimulate development of scientific information on soybean rust and provide a means for the rapid dissemination of data and material among those scientists worldwide whose assignments and interests encompass any aspect of the soybean rust problem.

Additional information on research conducted in fungal and bacterial diseases of soybeans may be found in Appendix III-A.

Virus diseases of soybeans. Studies on virus diseases of soybeans were established in the latter stages of the research contract. Work concentrated in describing and characterizing the nature of viruses causing mosaic diseases of soybeans. A new virus disease of soybeans, discovered in experimental fields in Puerto Rico, was found to be caused by a strain of cowpea mosaic virus, a beetle-transmitted virus that is also seed transmitted in cowpeas. All varieties of soybeans so far tested are susceptable to the virus and show very severe symptoms. Only rarely do infected plants produce seeds.

In cooperation with colleagues at the University of Puerto Rico, studies were undertaken on the etiology of the bean golden yellow mosaic and soybean yellow (or Rhynchosia) mosaic. Pathogens causing these diseases are whitefly-transmitted, had not heretofore been characterized, and were only presumed to be viruses. The studies have shown that the causal agent of bean golden yellow mosaic is an unusual virus perhaps belonging to a newly emerging but poorly understood class of virus pathogens from the tropics. Results of the studies on the bean disease should assist researchers in studying the whitefly-transmitted viruses of soybeans that are so serious in tropical America and Asia.

An unusual virus or virus complex isolated from soybeans in Spain is under study. The virus is thought to be caused by an unusual strain of soybean mosaic virus. Further work will be conducted to determine whether or not a second virus is involved in this soybean disease.

Cooperative comparative studies were conducted with INTSOY pest management specialists on the field spread of soybean mosaic virus at Urbana and Isabela, Puerto Rico. Soybean mosaic virus is thought to be spread by aphids in the field from infected seedlings arising from infected soybean seeds rather than from some outside alternative host plant. While little spread was detected in the winter season (January-April) study in Puerto Rico, extensive spread occurred in early August 1975 in Urbana during a 16-day period. The rapid spread of the virus corresponded to a time when preliminary evidence shows large numbers of winged aphids were present in the field. Further detailed work on the mechanism of virus transmission by aphids and the conditions conducive to and patterns of field spread are now underway. More complete information on the work in soybean virus disease studies may be found in Appendix III-B.

Other institutional research in soybean pathology. Four areas of research supportive of the INTSOY program are underway at various substations of the Agricultural Experiment Station, University of Puerto Rico.

Four soybean disease nurseries were established to aid in assessing the overall plant pathogen problem. A fungicide spray program has been established to determine the types of pathogens that can be controlled with the use of chemical barriers. Soybean seed quality trials have been established to test the seed quality of soybeans produced under tropical conditions as compared to certified soybean produced on the U.S. mainland. A tropical soybean pathology culture collection has been developed to provide a means by which to maintain a semipermanent record of fungal and bacterial organisms that have been found in the association with soybeans under tropical conditions. Further information may be found in Appendices III-C through III-F.

5. Soybean Food Use. Research was conducted in the following areas:

1. Initial studies were made on development of: (a) concepts for rapid preparation of weaning foods, and soybean cereal patties that could be fried and used as meat substitutes in the diet; (b) a procedure for preparation of a highly palatable soy beverage for village use; and (c) a filtering device for use in preparation of the soy beverage at the village level.

2. A study was made on the effects of using whole corn, different fractions of corn, brown rice, or whole wheat flour as ingredients in drum-dried soy-cereal weaning foods. Changes in organoleptic quality were observed as a result of changes in processing methods on raw ingredients.

3. Studies were carried out on the rate of water uptake and the development of tenderness by many varieties of soybeans under different soak/cook conditions and using different soak/cook solutions. Tenderness of the cooked soybeans was compared to many physical and chemical characteristics in an effort to find a predictor for tenderness.

4. Observations were made on the use of sodium and ammonium bicarbonate as tenderizing agents during the soaking and/or blanching steps processing soybeans prior to canning.

5. Protein efficiency ratios (PERs) were determined on many prototype foods made wholly or partly from "field" varieties of soybeans.

Data and detailed information for areas 3, 4 and 5 were given in the previous Annual Reports for this contract. Work on areas 1 and 2 is detailed in Appendix IV. A summary of each major project and sub-project follows:

1. Village-level processing of soybean based food products. A serious problem or deterrent to home or village industry utilization of soybeans is the long cooking time necessary to achieve acceptable tenderness. Whole soybeans, prepared according to accepted cooking methods, require soaking periods of 6 to 8 hours at about room temperature, followed by a cooking time of at least 2 hours. Concepts for preparing highly nutritious whole soybean based products that can be prepared in 30 to 40 minutes were developed and appear to be very promising. The first concept concerned products such as weaning or breakfast foods and soybean-cereal patties that could be fried and used as a substitute for meat in the diet. The weaning

foods could be prepared starting with the raw, dry bean in about 30 to 40 minutes total cooking time, plus a few minutes for grinding and maceration. The fried soy-cereal patty required a slightly longer preparation and cooking time due to the frying operation.

The second concept concerned the development of a procedure for preparation of a highly palatable soy beverage for village industry or home use. This concept uses a very low level of technology and requires a grinder which is capable of particle size reduction similar to that achieved in a Waring blender, cooking pots, and a filtering device. Presently, a beverage of about 2.5% protein can be consistently prepared, using this technique. Effort is now being directed towards developing a preparation procedure that will result in a finished beverage containing 3% protein. Although extensive taste panels have not been conducted, it appears that a bland beverage, completely free from "beany" or "painty" off-flavor, and with a very acceptable texture or mouth feel can be prepared. Three filtering devices for this soy beverage were constructed and tested during 1975-76. The filtering device which appeared most promising, was a long tube or sock which was fabricated from polyester cloth. Two 1" x 2" boards, which were clamped across the bottom, serve as a rolling and squeezing device for removing the liquid.

The concepts for preparation of soy based products at village level generally require that beans and other cereals be broken and/or ground for processing. Thus, a low cost mill that might be suitable for breaking or grinding raw material for either a small industry or for village use for the general population was located and ordered. It was received in May, 1976. The mill appears suitable for grinding dry materials, is of relatively high capacity, and low in cost. The unit is a typical hammermill equipped with 6 screens ranging from 1/8" to 3/8" screen size opening. It is constructed of mild and hardened steel and was purchased from Decker Manufacturing Co., Rockford, Illinoi for about $700. It will be evaluated for grinding all types of dry soy and cereal products.

2. Drum-dried cereal-soy weaning or breakfast foods. The overall aim of this research was to use whole soybeans to fortify cereals which are traditionally used in developing countries in order to increase their protein quantity and quality. The emphasis was on simplicity of process and organoleptic acceptability of product.

Whole corn was milled and fractionated to produce 4 corn fractions: (1) ground whole corn; (2) the fraction retained on a 22 wire mesh screen; (3) the fraction retained on a 32 wire mesh screen; and (4) the fraction passing through a 32 wire mesh screen (pan fraction). Each fraction was further ground through a hammermill in order to equalize particle size.

Whole wheat flour was purchased locally and used in that form. Whole brown rice was purchased locally and ground in a hammermill prior to use. Drum-dried soy-cereal flakes were prepared by drum-drying a slurry of cooked ground soybeans and the cereal flour.

Whole soybeans were cooked and ground to a smooth slurry. The desired cereal was mixed with the soy slurry. In some experiments, additional processing steps were used. The soy cereal slurry was then drum dried.

Organoleptic and nutritional tests indicated that the pan fraction of corn was superior to other fractions tested. A (1:4) mixture of soy:corn (pan fraction) was at least equivalent organoleptically and nutritionally to other soy:corn mixtures tested. Increasing the content of soy, or use of other fractions of corn, resulted in lower organoleptic scores. PER values for soy:corn flakes ranged from 2.1 to 2.5. Gelatinization of the soy:corn mixture prior to drum drying had little effect on acceptability or upon the PER.

Similar trials were conducted using flour made from brown rice and whole-wheat flour. Up to 20% soy could be added to the rice without any changes in organoleptic scores. In these experiments, addition of soy to the whole-wheat flour resulted in reduced organoleptic scores. The reason for this is not clear since previous experiments had indicated that soy:wheat combinations were highly desirable. In all the soy:cereal experiments, soybeans were blanched in tap water. From previous experiments it was known that blanching soybeans in sodium bicarbonate will result in improved flavor and texture. Therefore this technique will be used in future experiments, particularly with soy-wheat mixtures.

Neither gelatinization of the slurry before drum drying nor addition of bicarbonates to the soy:wheat or soy:rice slurries resulted in significant changes in organoleptic scores.

Sodium or ammonium bicarbonate was added to certain soy-cereal slurries prior to drum drying in order to attempt to reduce the hang-up which appeared to be associated with the corn hull. (This procedure is not normally used in the University of Illinois Food Processing laboratory since it was recognized that the bicarbonate might accumulate in the product. Due to residual bicarbonate in the product, the amount used must be reduced and more carefully controlled, which may not be practical at the village level). Addition of 0.05% sodium bicarbonate to the slurry resulted in the highest organoleptic scores and lowest hang-up. At higher concentrations of sodium bicarbonate, a distinct sodium bicarbonate or soapy off-flavor resulted in the final product. Up to 5.0% ammonium bicarbonate could be added to the soy:corn slurry before drum drying without significant changes in flavor or off-flavor. In the tests using ammonium bicarbonate, organoleptic scores for flavor and hang-up were highest when 0.1% ammonium bicarbonate was added.

3-A. Water uptake by soybeans. During the early part of this study, it appeared important to study certain factors which were involved in producing tender and organoleptically desirable cooked whole soybeans. Studies were undertaken, therefore, to study the effects of variety and processing methods on the characteristics of cooked whole soybeans. A second study (see section 4) was made on the effect of different processes used in canning soybeans.

This experiment was designed to find the optimum conditions for highest uptake of water. Temperature was the most important factor which determined the rate of water uptake by soybeans during soaking. A plot of rate of water uptake versus temperature resulted in a biphasic curve with a sharp break at 60 to 65°C. Up to 60°C the rate of water uptake increased, while between 65 and 90°C the rate of water uptake was nearly constant.

The amount of water uptake was lowered by increased temperature and by the presence of bicarbonate in the soaking solution.

There was no significant difference in the amount of water uptake of year-old and freshly harvested Kanrich or Corsoy variety soybeans.

The increase in weight of 24 varieties of soybeans soaked in 0.5% sodium bicarbonate solution at 25°C was 96.4% ± 6.3% (mean ± standard deviation) after 6 hours and 106.5 ± 9.4% after 24 hours respectively. The amount or rate of water uptake did not appear to correlate to tenderness of cooked soybeans.

3-B. Effect of variety upon tenderness of cooked whole soybeans. A test was carried out on eight U.S. varieties of soybeans using 12 combinations of soaking conditions and soaking solutions. These tests showed: (a) the tenderness of cooked soybeans of the eight varieties tested was increased by longer soaking times and by use of bicarbonate in the soak and blanch solutions; (b) varieties exhibited substantial differences in tenderness (shear press peak height) after cooking. However, no variety was consistently more tender than the others.

A detailed survey was made on 24 varieties of soybeans to attempt to find chemical properties, physical properties, or cooking characteristics which might be used to predict the tenderness of cooked whole soybeans. All samples used except one (Corsoy, 1973 crop) were from the 1974 crop. (See Table 1). Evaluations of soybean varieties demonstrated that the soaking/cooking solution was the most important factor in developing tenderness in the cooked whole soybeans. The results are summarized in the following table:

TABLE 1. MEAN SHEAR PRESS PEAK HEIGHT (psi) for 24 VARIETIES OF COOKED WHOLE SOYBEANS

VARIABLE	TIME	SOAK/COOK COMBINATION			
Soaking sol'n	18 hr	0.5% $NaHCO_3$	Tap water	No Soak	No Soak
Cooking sol'n	1 hr	0.5% $HaHCO_3$	Tap water	0.5% NaHCO	Tap water
Means for all Samples Tested(psi)		19.1	58.4	49.8	74.4

When only varietal differences were considered, the mean shear press values ranged from 40.3 to 64.5 pounds per square inch (psi). The four processing methods used accounted for a 400% variation in tenderness of the cooked beans, whereas the varieties tested only accounted for a 60% variation in tenderness. When the soybean varieties were ranked from tender to hard within each treatment, the relative position of each variety depended upon the soaking and blanching solution used.

Over 20 characteristics were measured to test their correlation with tenderness of the final cooked whole soybean. Of the physical and chemical factors measured, only a few appeared to correlate with the tenderness of the cooked whole soybeans. These factors included percent moisture in the

TABLE 2. VARIETIES TESTED AND WHERE PRODUCED

Variety	Produced	Variety	Produced
Amsoy	Illinois	Hardee	Florida
Amsoy 71	Illinois	Hark	Illinois
Beeson	Illinois	Hodgson	Minnesota
Bonus	Illinois	Improved Pelican	Louisiana
Bossier	Louisiana	Kanrich	Illinois
Calland	Illinois	Pickett 71	Arkansas
Clark 63	Illinois	Semmes	Arkansas
Cobb	Florida	Shakkin Nashi	Japan
Coker Hampton 266A	Arkansas	Swift	Minnesota
Corsoy (1973)	Illinois	Tracy	Arkansas
Corsoy	Illinois	Woodworth	Illinois
Columbus	Kansas	Wayne	Illinois
Davis	Arkansas	Wells	Illinois
Forrest	Arkansas	Williams	Illinois

dry soybeans (P = .01), weight per bean, volume per bean, cooked weight per bean, and cooked volume per bean (P = 0.05). Thus, large seed size and maximum change in size during soaking and cooking resulted in greatest tenderness. The results are tentative since climate or crop year must be considered as a possible important variable. Tests using Corsoy and Kanrich varieties from both 1973 and 1974 crops support this statement. Similar tests will be carried out using soybeans from the 1975 and 1976 crops.

4. Use of bicarbonates for processing during preparation of canned soybeans. Canned foods are well recognized as providing convenient, easily prepared, stable products. Canned soybeans might offer similar advantages. They could also be used as relief or emergency supplies.

A study was made on the use of sodium and ammonium bicarbonate as tenderizing agents during the soaking and/or blanching steps of processing prior to canning soybeans. Ammonium bicarbonate does not appear to have been used for tenderizing by the canning industry previously. This study and previous experiments demonstrated that properly processed and flavored, canned soybeans provide an attractive and convenient form of food. The following observations and conclusions were made during these experiments.

Both ammonium bicarbonate and sodium bicarbonate can be used to tenderize soybeans before canning. The effect of bicarbonates depended upon their concentration and the processing steps during which they were used.

Use of either sodium or ammonium bicarbonate only during soaking was more effective for tenderizing than use only during blanching. Treatment during soaking was as effective as treatment during both soaking and blanching. Soaking appeared to be the processing step which most effectively tenderized the soybeans as observed by taste panelists and as measured with a shear press. This is contrary to previous observations made on soybeans soaked and cooked at atmospheric pressure. At atmospheric pressure, a combination of soaking and cooking in bicarbonate was most effective.

The tenderness of the pre-blanched, canned soybean varied with the bicarbonate concentration used. Maximum tenderness was obtained with the highest concentration of the bicarbonate. However, soybeans prepared with distilled water were also soft.

The cooked soybeans were more tender as the pH of the ammonium bicarbonate used was increased from 4.0 to 9.0. The pH effect was more pronounced with ammonium bicarbonate than with sodium bicarbonate. In both cases, the most desirable pH range, based on a combination of flavor and texture, was about pH 7 to 8.

Taste panelists detected no significant difference in flavor or off-flavor as the result of the use of bicarbonates. Taste panelists did not detect changes in tenderness, flavor or off-flavor during storage.

During storage, the canned soybeans became less tender as measured using the LEE-Kramer shear press. Tenderness decreased faster at higher storage temperatures. The decrease in tenderness was less when bicarbonates were used for processing than when bicarbonates were not used.

The use of bicarbonates during soaking and/or blanching increased the pH of the brine in which soybeans were canned, and higher concentrations of bicarbonate resulted in a higher pH. The pH of all products was in the acceptable range, i.e., 6.1 to 6.8 even though the bicarbonate solutions used always had a pH of 7.5.

The pH of the brine changed during storage. In general the brine tended to approach the pH range 6.1 to 6.3. The change of pH was more rapid at higher temperatures.

5. Nutritional evaluations. Three protein efficiency ratio (PER) studies were conducted during the course of this contract in order to study: (a) the effects of different processing methods; (b) combination with different cereals; (c) the effect of added methionine; and (d) the effect of using different corn fractions when making a drum-dried soy-corn weaning food. In most cases, the soy was prepared by cooking, grinding and drum drying the whole soybean slurry. Soy:cereal or soy:fruit mixtures were prepared by adding the second ingredient to a slurry of the cooked whole soybeans and drum drying the mixture. The soybean beverage base was prepared by cooking whole soybeans, grinding with water (10-12% slurry) and homogenizing. Details were given in the annual reports for 1974-75.

The PERs for whole soybeans prepared in various forms were about 1.9 - 2.0. For soybean cereal mixtures, the PERs were about 2.1 - 2.4 which indicated the complementary effect of cereal and soy proteins. Methionine, when added, increased the PER except for soy:banana flakes. Methionine was most effective in increasing the PER when added to 100% soybean products. The PER for a 1:1 mixture of soybean-banana was 1.4 in each of two trials. Addition of methionine did not correct this low PER. The PER was raised to 2.0 by drum drying the soybean, freeze drying the banana, and mixing the two before the feeding trial. Amino acid analysis of soy-banana drum dried as a mixture and soybean plus banana, (dried and then mixed) demonstrated that the amino acid composition was approximately the same. At this time we do not have an explanation for the low PER of the drum dried soybean-banana mixture.

E. Dissemination and Utilization of Research Results

Dissemination of the results of research associated with the INTSOY program, and more specifically with Research Contract AID/CM/ta-c-73-19, has been accelerated and represents one of the major accomplishments of the Contract in its contribution to the development of a world wide soybean research network. Two primary factors were involved in the accelerated rate of reporting of research findings. A good start had been made under a predecessor AID contract (AID/CSD-3292, Development and Food Utilization of Soybeans) in the areas of variety improvement, information support systems, and in soybean food processing. The continued support by the Agency for soybean research under this contract and the encouragement given by the Agency under other instruments (companion 211(d) grants to UIUC and UPR/M, task orders for outreach activities and grants for regional conferences) clearly signalled the Agency's interest and commitment to the development of a soybean resource base with UIUC providing the leadership role. The second major factor derives from the unique characteristic of INTSOY that all research is based on the multidisciplinary approach to a total soybean program. The new dimension that INTSOY provides is a multidisciplinary staff that can study problems and

their solutions within a system's context. The ripple effect of the INTSOY Research Contract staff on the output of publications in refereed journals, experiment station bulletins, conference proceedings and research journals and letters is best illustrated in Appendix V. Over 100 articles reporting on research associated with this Contract are reported. Obviously, not all of the research reported was wholly financed by the research contract. But Contract staff provided impetus, encouragement, support or advice as well as direct participation in many cases.

A major tool in the dissemination of information has been the INTSOY Publications Series. This Series has added to the joint UIUC and UPR/Mayaguez soybean response capability as well as providing a means of making research results readily available to those interested in tropical and subtropical production and use of soybeans. Nine publications have been issued and one is in the final stages of production. They are:

1. Godfrey, G. L. (ed.), Selected Literature of Soybean Entomology, University of Illinois International Agriculture Publications, INTSOY Series No. 1. 221 + xxi pp. April 1974.

2. Proceedings of the Workshop on Soybeans for Tropical and Subtropical Conditions. University of Puerto Rico, Mayaguez Campus. INTSOY Series No. 2. 184 pp. May 1974.

3. Williams, S. W. and Rathod, K. L., A Case Study of Expeller Production of Soybean Flour in India. University of Illinois International Agriculture Publications, INTSOY Series No. 3. 12 + iii pp. April 1974.

4. von Oppen, M. K., Soybean Processing in India: A Location Study on an Industry to Come. University of Illinois International Agriculture Publications, INTSOY Series No. 4. 35 pp. July 1974.

5. Williams, S. W., Hendrix, W. E., and von Oppen, M. K., Potential Production of Soybeans in North Central India. University of Illinois International Agriculture Publications, INTSOY Series No. 5. 21 + iv pp. August 1974.

6. Whigham, D. K. (ed.), Soybean Production, Protection and Utilization--Proceedings of a Conference for Scientists of Africa, the Middle East, and South Asia. University of Illinois International Agriculture Publications, INTSOY Series No. 6. 266 pp. March 1975.

7. Sinclair, J. B. and Dhingra, O. D., An Annotated Bibliography of Soybean Diseases, 1882-1974. University of Illinois International Agriculture Publications, INTSOY Series No. 7. 280 pp. December 1975.

8. Whigham, D. K., International Soybean Variety Experiment, First Report of Results. University of Illinois International Agriculture Publications, INTSOY Series No. 8. 161 pp. October 1975.

9. Hymowitz, T., Carmer, S. G., and Newell, C. A., Soybean Cultivars Released in the United States and Canada: Morphological Descriptions and Responses to Selected Foliar Stem and Root Diseases. University of Illinois International Agriculture Publications, INTSOY Series No. 9. 31 pp. January 1976.

10. Goodman, R. M. (ed.), Expanding the Use of Soybeans, Proceedings of a Conference for Asia and Oceania. University of Illinois International Agriculture Publications, INTSOY Series No. 10 (in process).

1. Summary by Subject-Matter Areas. Within the INTSOY subject matter areas research staff worked in a number of ways to extend information within the international soybean workers network. A summary of examples follows:

a. Soybean variety development. Seminars were presented to staff and students of the Department of Agronomy UIUC about the overall INTSOY program and results obtained from ISVEX. A seminar was also presented before the Cooperative State Research Service Review Committee as part of the Department of Agronomy activities. Papers were presented at the World Soybean Research Conference held in Urbana/Champaign in August, 1975 and at three Regional Soybean Conferences in Mayaguez, Puerto Rico; Addis Ababa, Ethiopia; and Chiang Mai, Thailand, reporting on results obtained from ISVEX 1 and 2.

Copies of Number 8 in the INTSOY Publications Series were sent to all ISVEX cooperators and many other scientists in LDCs. INTSOY Newsletter Number 7 carried a summary of the INTSOY genetic improvement program which included the breeding program in Puerto Rico, the SPOT and the ISVEX.

Several countries have used results from the ISVEX at local sites to identify cultivars with high potential in local environments. The cultivars are then increased locally or imported on a large scale for commercial production.

The Utah State University AID Contract for Agricultural Technology Transfer and Utilization personnel have used the ISVEX instructions and data book as a guide for their corn and soybean trials. Cultivars identified by the ISVEX are being included in the Utah soybean tests. The Centro Internacional de Agricultura Tropical (CIAT) has recently established an International Yield and Adaptation Nursery for Dry Beans (IBYAN). Both the instructions and the data book are patterned after these of ISVEX.

Seminars on the seed quality studies have been presented to staff and students of the Department of Agronomy UIUC. Several papers have been prepared and submitted for publication in refereed journals.

A paper was presented in 1975 at American Society of Agronomy annual meeting on screening soybean germplasm for daylength sensitivity. Seminars have been presented to staff and students and papers have been submitted for publication.

b. Taxonomic information retrieval system (TAXIR). A major publication "Soybean Cultivars Released in the United States and Canada: Morphological Descriptions and Responses to Selected Foliar, Stem and Root Diseases" was completed and published as Number 9 in the INTSOY Publication Series. This publication presents data on 331 cultivars in compact tabular form. In addition to description of the cultivars the degree of resistance/susceptibility to ten foliar, stem and root diseases is described. This publication was sent to all ISVEX cooperators.

c. Insect control and entomological studies. Requests received and filled by the two insect reference collections, SIRIC and IRCSA, were major components of the dissemination of information in this area. Requests for information are increasing as the knowledge of availability of this service becomes available to international soybean workers. For example, the number of requests filled by SIRIC in 1975-76 increased 70 percent over those filled in the previous year. IRCSA now contains over 100,000 specimens including 800 species from 25 countries. Linkages have been established with many U.S. institutions, national institutions in LDCs, and international organizations. There have been increasing demands for IRCSA services by LDCs and U.S. institutions. The resource information contained in IRCSA has begun to be utilized by and incorporated into soybean insect pest management programs.

Dissemination of results has been furthered by publications and advisory activities. The bibliographies of soybean arthropod pests have helped many researchers and extension personnel in LDCs by allowing them access to literature of major pests. The compilation of "Selected Literature of Soybean Entomology," INTSOY Publication Series No. 1, has helped workers overseas get an idea of soybean arthropod research in a handy packet form. Already over 1,000 copies of this publication have been distributed and the publication is in its second printing. Papers and proceedings of regional soybean workshops have helped greatly in getting across ideas relevant to soybean pest management concepts. A guideline for soybean insect pest management in Illinois has been prepared and its applicability for use in other countries is being tested.

d. Soybean pathology. All pertinent research data from studies of fungus or virus diseases affecting soybeans is prepared for publication as soon as possible and is disseminated through professional journals, books, proceedings of conferences and in seminars in the U.S. and other countries. In the past two years, the soybean fungal pathologist has presented results of research at three INTSOY regional conferences (Puerto Rico, Ethiopia, and Thailand); at the World Soybean Research Conference held at

Urbana-Champaign; at Funk Seed International, Bloomington, Illinois; at professional society meetings and at workshops and seminars in Colombia, Brasil, Costa Rica, Egypt, Iran, Korea, Malaysia, and Taiwan.

The soybean virus pathologist has prepared a bibliography listing publications on soybean virus diseases and soybean viruses. It is as yet unpublished but cooperating pathologists are provided with xeroxed copies upon request. Research results have been described in seminars and conferences at the University of Arkansas, the Ohio Agricultural Research and Development Center, and the Institute Nacional de Investigaciones Agrarias, Madrid. Papers were delivered at the World Soybean Research Conference, Urbana-Champaign and at the INTSOY Regional Soybean Conference, Thailand.

The impact of soybean pathology research is felt both domestically and internationally. The Illinois Crop Improvement Association has agreed to finance research by the Department of Plant Pathology in which the INTSOY fungal pathologist will participate to assess the present methods of measuring soybean seed quality. The role of seed borne micro-organisms on soybean seed germination has not been understood by most seed-testing laboratories. In cooperation with ICIA, new methods are being developed for measuring soybean seed quality and predicting field performance.

As a result of seminars presented to staff of Funk Seeds International, that organization is changing its methods for assessing seed quality and use of fungicides for control of seed borne fungi in their seed production fields.

e. Soybean food uses. Eleven brief simply written circulars which describe some of the methods for using whole soybeans directly for food were prepared and circulated for use by people in developing countries. These circulars were:

(1) Home Preparation of Home Cooked Soybeans
(2) Home Preparation of Roasted Soybeans
(3) Preparation of Mixed Bean Salad at Home
(4) Home Preparation of Soybean-Banana Weaning Food
(5) Preparation of Soybean Dal--Village Level
(6) Manufacture of Canned Soybean Products
(7) Manufacture of Whole Soybean Powder by Roller (Drum) Drying
(8) Manufacture of Soybean-Corn (1:1) in Powder by Roller Drying
(9) Manufacture of Soybean-Rice (1:1) Powder by Roller Drying
(10) Manufacture of Soybean-Banana (1:1) Powder by Roller Drying
(11) Preparation of Soybean Dal--Processing Plant

Papers were presented at the three Regional Soybean Conferences and at professional society meetings. Seminars and demonstrations of methods of preparing simple soy-based foods were presented in Ethiopia, Kenya, Uruguay, Ghana, Brasil, The Philippines and Sri Lanka.

The food science staff conducted a review of existing literature which cited processes and concepts which could be expected to produce interesting, acceptable, and adaptable products for use on home or village industry scale. The study was reported in the 1975 Annual Report and is available in xerox form.

2. The INTSOY Newsletter. The INTSOY Newsletter is intended to provide communication among those interested in soybeans on a world scale. It was first issued in August 1974 and is released quarterly. Seven issues have been released. Five hundred copies of the first issue were distributed. Requests for names to be added have resulted in an expansion of the mailing list to over 1,200, with over half the issues going to overseas addresses.

3. Regional Workshops. A successful blend of informal training and professional interchange has been a central feature of three INTSOY-sponsored regional soybean conferences. One each has been held for soybean workers in the Latin America-Caribbean region; for workers in Africa, the Middle East and South Asia; and for workers in Asia and Oceania. The general purpose of each workshop was to bring scientists together to consider the potential of soybeans as a major world food crop. The theme of each conference was the exchange of information and research findings. Reports from each country represented at the conference gave participants opportunity to compare their plans, activities, and programs.

Each conference was well attended. The first conference, held February 4-6, 1974, on the University of Puerto Rico Mayaguez Campus, had 71 participants from 12 countries; the second conference held October 14-17, 1974 at Addis Ababa, Ethiopia, attracted 97 participants from 24 countries; the most recent conference held February 23-27, 1976 in Chiang Mai, Thailand attracted 225 participants from 21 countries.

General sessions were devoted to the presentation of scientific papers on various aspects of production, protection, economics and utilization. Some conferences featured symposia focusing on special problems associated with soybean production, protection or use. Field trips to experiment stations were features of each conference. These conferences have been a very effective means of encouraging exchange of ideas and information among soybean workers across national lines. The proceedings (INTSOY Series 2, 6, and 10) are constantly being requested.

4. Training Courses. In cooperation with the United States Department of Agriculture's Office of International Training and AID, two short-term applied training courses have been developed to provide a general experience to soybean workers for those interested in soybean development, from other nations. One course, Soybean Processing for Food Uses, has completed two successful sessions. The second course, Technical and Economic Aspects of Soybean Production, completed its first session in the summer of 1975 and will be offered again in May 1976.

The general development objectives of the soybean processing course are to give participants the opportunities to learn the principles and processes involved in use of soybeans and soybean products for human foods, to teach the concepts and procedures for processing of whole soybeans, and then apply the knowledge gained to country development objectives in the use of

soybeans as an improved source of protein and calories. The first course welcomed 13 persons from 10 different countries including Colombia, Philippines, Korea, Brasil, Kenya, Sri Lanka, Ghana, Costa Rica, Thailand, and Nicaragua. The second course had 15 participants from 12 countries including Bangladesh, Afghanistan, Egypt, Republic of China, Colombia, Iran, Nigeria, Nepal, Brasil, India, Sri Lanka, and Peru.

While the course in soybean processing is an intensive five-week experience, the course on Technical and Economic Aspects of Soybean Production is of longer duration, approximately four months, and carries through the major part of the Illinois soybean growing season. The general development objectives are: to learn the technical and economic principles and practices of soybean production; to study the research, educational and regulatory functions supportive of a soybean industry; to understand the potential use of soybean to alleviate protein-calorie deficiency problems; and to increase participants' knowledge and understanding of basic nature and characteristics of the soybean plant; the cultural practices required for its production; factors affecting seed quality; and the adaptation of the technology required for soybean production to local conditions. The first course, given May-August 1975, welcomed 16 persons from 15 different countries, including Iran, Philippines, Uruguay, Jamaica, Korea, Chile, Liberia, El Salvador, Sri Lanka, Lesotho, Ghana, Nicaragua, Zambia, Burma, and Costa Rica.

Planning is underway to offer a condensed version of the soybean production short course at selected overseas locations. The general objectives will be to provide course participants with an adequate understanding of the soybean crop and its management needs to be able to successfully grow the crop, to recognize the production hazards, and to evaluate the consequences of these hazards in terms of soybean productivity and quality. USDA's Office of International Training is cooperating in the development of the course which may be offered some time in 1977.

5. Country Programs. Country programs provide a direct means of disseminating and utilizing the results of research obtained under the research contract. Assistance on country programs has been provided through support of individual countries, AID, and international organizations and is summarized below:

a. Soybean development in Sri Lanka, supported by the United Nations Development Program and the Food and Agriculture Organization of the United Nations. Initially funded for 30 months beginning April 1, 1975, the program is anticipated to be extended for an additional five years from November 1, 1977. Assistance is being provided in the areas of agronomy, plant breeding, plant pathology, entomology, cost of production, marketing, processing, food science (utilization), agricultural engineering and weed control. An INTSOY proposal for the establishment of a pilot plant research facility for development of soybean food products and processes, which is ancillary to the FAO project is under consideration for financial support by several agencies.

b. AID mission supported country programs. Under AID Basic Ordering Agreement-Task Order arrangements, 8 projects were undertaken

during the period of the research contract. They included:

(1) AID/BOA-73-30 Task Order #1 Guyana (completed) 10.5 man months service. Assistance was provided in the areas of agronomy, plant breeding, cost of production and marketing, seed technology, microbiology, processing (separation of oil and protein) in food science (utilization).

(2) AID/BOA-73-30 Task Order #2 Uruguay (completed) .5 man months.

(3) AID/BOA-73-30 Task Order #3 Peru (completed) .25 man months.

(4) AID/BOA-1109 Task Order #1 Bangladesh (completed) .75 man months. Assistance to Uruguay, Peru and Bangladesh consisted of brief one-man mission to determine the feasibility of soybean development project.

(5) AID/BOA-1109 Task Order #2 Peru (in progress) 22 man months service. Assistance is being provided in the areas of agronomy, plant breeding, extension, microbiology, cost of production and marketing and food science (utilization). The Peruvian government has requested a long term contract with technical assistance, training of local personnel and equipment components or the development of a total soybean program.

(6) AID/BOA-1109 Task Order #3 Ecuador (in progress) 4.5 man months service. Assistance is being given in plant breeding and in agronomy.

(7) AID/BOA-1109 Task Order #4 Zaire (completed) 1 man month service. From an associated university INTSOY provided an extension agronomist as part of a three man team (an AID agricultural officer, a 211(d) soils specialist from Cornell University and the INTSOY representative from Iowa State University) to review a proposed AID sponsored project in food legume production.

(8) AID/BOA-1109 Task Order #5 Thailand (in progress) 3 man months service. Assistance is being given in soil microbiology (legume inoculant) and cost of legume inoculant production to assist the government of Thailand in deciding whether they should develop internal capability to produce soybean inoculant or import it.

Country support only has been provided to two requesting countries. A two-man team spent a brief time in Saudi Arabia assessing the soybean potential of that country. Assistance was given to Ivory Coast by providing a team of INTSOY and Mississippi State University personnel to advise on soybean development in that country.

6. Formalized Linkages with National and International Organizations. INTSOY has demonstrated that administrative mechanisms can be developed for

cooperation with national and international organizations. One effective means is a general Memorandum of Understanding with Letters of Agreement to provide for specific projects and activities. This mechanism provides excellent opportunity for dissemination and utilization of research results. Memoranda of Understanding have been completed with the following organizations:

a. University of Puerto Rico/Mayaguez Campus. This is the primary relationship in INTSOY providing for joining of the temperate and tropical based universities.

b. International Institute of Tropical Agriculture (IITA) Nigeria. This provides a means for INTSOY to work with and through an international center with soybeans as part of their mandate. It is anticipated that an INTSOY research and outreach team, fully integrated with the IITA Grain Legume Improvement Program Staff, will be based at IITA. However, separate funds to implement work under this Memorandum have not yet been identified.

c. Asian Vegetable Research and Development Center (AVRDC) Taiwan. The general objectives are similar to the Memorandum written with IITA.

d. Fundacao Instituto Agronomico do Parana (IAPAR) Brasil. This provides the opportunity to join with the second most important soybean producing country to expand the use of soybeans for human food both there and in low income countries of the tropics and subtropics. The recent location of the National Soybean Center at IAPAR provides expanded opportunities for cooperative efforts in serving the needs of tropical and subtropical countries, particularly in South America.

e. Office of Rural Development, Ministry of Agriculture and Fisheries, Korea. Korea has had a significant experience in soybean production and has an aggressive crop improvement program that includes soybeans. Cooperation here is planned as a technological bridge between the temperate and tropical areas of the Orient and Asia.

f. College of Agriculture, University of Tehran, Karaj, Iran and College of Agriculture and Animal Husbandry, Rezaiyeh, Iran. Memoranda of Understanding have been completed with these two Colleges of Agriculture and discussions are well advanced with other Iran organizations. The objective is to develop cooperative research, education and developmental work on expanded use of soybeans and production under irrigated conditions typical of Middle Eastern countries.

Discussions are underway with personnel of other organizations including additional international centers such as CIAT with interest in soybeans and with research organizations in tropical countries, such as the Philippines Council for Agriculture and Resources Research.

7. Other INTSOY Linkages. INTSOY has a host of relations with organizations and individuals demonstrating a basic organizational concept of cooperation with all who have interests congruent with the INTSOY mission "to expand the use of soybeans for human food." The following is a list of these organizations:

a. Organizations in 90 countries through the International Soybean Evaluation Experiment (ISVEX). The extent of this network and names of organizations are listed in Appendix I-A. Six international agencies have participated in the ISVEX:

(1) Food and Agriculture Organization of the United Nations has used the ISVEX for testing in a number of Middle East and North African countries over the past four years.

(2) The French Institut de Recherches Agronomiques Tropicales et Des Cultures Vivrieres (IRAT) used ISVEX in 11 countries of Africa and Meso-America.

(3) The International Rice Research Institute (IRRI) has been cooperating for four years with INTSOY by testing ISVEX in Indonesia as part of the outreach multiple cropping activities. IRRI and INTSOY operated in a similar manner in Sri Lanka during 1973 and 1974.

(4) The Southeast Asia Regional Center for Graduate Study in Research and Agriculture (SEARCA) and INTSOY prepared a joint variety trial for testing in Southeast Asia in 1975. Nine entries were provided by SEARCA and eight came from INTSOY. Results of these experiments were shared by both organizations and the cooperating country.

(5) The International Institute of Tropical Agriculture (IITA) and INTSOY have initiated a joint variety trial which is being distributed to approximately 30 countries in tropical Africa in 1976. Each organization provides eight cultivars for the INTSOY/IITA trials, results of which will be shared by both organizations and the cooperating countries.

b. Nitrogen Fixation by Tropical Agricultural Legumes (NIFTAL), University of Hawaii/AID contract.

c. United States Department of Agriculture Regional Soybean Laboratory at Urbana, Illinois and Stoneville, Mississippi.

d. Kansas State University Food and Feed Grain Institute.

e. Mississippi State University Seed Technology Laboratory.

f. University Consortium on Soils of the Tropics (Cornell University, University of Hawaii, North Carolina State University, Prairie View A & M College, University of Puerto Rico).

g. North Carolina State University, AID Root Knot Nematode Project.

h. U.S. University personnel on task orders and other projects--Iowa State University, Purdue University, Texas A & M University, University of Florida, and Cornell University.

i. Private sector employees on task orders and other projects--Swift & Company, Potash Institute of North America, Agricultural Laboratories, Inc., and Research Seeds, Inc.

j. International Board for Plant Genetic Resources (IBPGR). INTSOY has been suggested as the coordinator for soybean germplasm collection activities throughout the world to prevent genetic erosion (loss of genotypes).

F. Administration and Budget

Economy of professional and support staff characterized the administration of the research contract. From a skeletal staff at the outset of the contract, judicious additions were made in the key area of plant protection (insects and diseases). The associate director located at the University of Puerto Rico Mayaguez Campus contributed to the planning and implementation of cooperative work there to a far greater extent than the time he was officially assigned to the contract.

The contributions of the various support personnel to the overall success in attaining the contract objectives is greatfully acknowledged. An uncommonly talented and dedicated group, they were a tremendous asset to the project.

By the end of the contract, the professional group numbered 6.75 full-time equivalent staff and assisted by 9.0 full-time equivalent support personnel. A listing of all personnel who served on the research contract is presented on pages 32 and 33.

G. A New Research Contract

The commitment to the development of a soybean resource base, shared by the Agency and INTSOY, goes beyond the termination date of Research Contract AID/CM/ta-c-73-19.

On April 1, 1976 a new instrument takes effect extending soybean research activities for an additional three years and permitting expansion into the new areas of soybean seed storage technology and Rhizobium production technology. Work on home and village level processing of whole soybeans for human food will be phased out of the new contract in anticipation of support from other sources within the Agency.

Research will continue in soybean variety development and protection against soybean diseases and insects. The complementarity of interests of the total INTSOY program will extend the effective utilization of findings within the expanding worldwide network of soybean development workers.

Funds for contract operations were generally adequate and available on a timely basis although greater support for publications, materials and supplies would have been put to good use.

A summary of expenditure is given below. It should be noted that the third-year expenditures include amounts obligated by but not paid at the time this report was prepared. Adjustments will be reflected in the final billing submitted by the Grants and Contracts Office.

Summary of Expenditures

April 1, 1973-March 31, 1976*

Line item	4/1/73-3/31/74	4/1/74-3/31/75	4/1/76-3/31/76	4/1/73-3/31/76
I. Salaries and wages	$ 84,110	$129,860	$219,550	$433,520
A. Professional staff	(55,980)	(91,765)	(117,305)	(265,050)
B. Support staff	(21,740)	(34,300)	(82,155)	(138,195)
C. Wages	(6,390)	(3,795)	(20,090)	(30,275)
II. Fringe benefits	4,600	11,315	20,310	36,225
III. Indirect costs	52,990	81,640	143,660	278,290
IV. Travel and transportation	18,920	25,855	45,550	90,355
A. U.S. (includes Puerto Rico)	(7,795)	(9,965)	(7,900)	(25,660)
B. International	(11,125)	(15,920)	(37,650)	(64,695)
V. Other direct costs	5,255	5,900	63,730	74,885
VI. Equipment, materials and supplies	10,515	26,755	40,745	78,015
Total	$176,390	$281,355	$533,545*	$991,290*

*Includes obligation not paid at time of submission of final report.

Professional Staff

Area	Percent time	Service dates
Administration		
R. Abrams* Associate Director	25	August '74-present
E. R. Leng, Project Director	50	April '73-December '73
T. A. McCowen, Assistant Director	25	September '73-present
W. N. Thompson, Director INTSOY	25	December '73-present
Agricultural Entomology		
G. K. Godfrey, Assistant Professor	50	April '73-February '76
M. E. Irwin, Assistant Professor	100	October '74-present
Agronomy		
R. Dunker, Assistant Agronomist	100	January '74-present
C. N. Hittle, Professor	25	August '74-present
H. C. Minor, Assistant Professor	100	December '75-present
D. K. Whigham, Assistant Professor	75	April '73-present
Food Science		
L. K. Ferrier, Assistant Professor	75	April '73-present
A. I. Nelson, Professor	25	August '74-present
Plant Pathology		
R. M. Goodman, Assistant Professor	75	August '74-present
P. Sangowonse, Research Fellow	100	August '74-February '75
J. B. Sinclair, Professor	25	August '74-present

*At University of Puerto Rico, Mayaguez Campus

Support Staff

Area	Percent time	Service dates
Administration		
Patricia Cunningham, Secretary	100	January '76-present
Melissa Neeley, Editor	100	December '75-March '76
Deanna Taeger, Secretary	100	August '74-present
Agricultural Entomology		
Jenny Kogan, Bibliographer	50	June '75-March '76
Martha Nichols, Research Assistant	100	April '73-August '74
Agronomy		
Helen Burnsmier, Typing Clerk	100	March '74-present
Floyd Collins, Research Assistant	20	April '73-June '74
Margaret Endsley, Secretary	100	January '76-present
Candace Morrison, Secretary	100	April '75-December '75
Cristine Newell, Research Associate	100	August '74-present
C. R. Nissly, Research Assistant	50	April '73-present
M. D. Tedia, Research Assistant	50	April '73-September '73
Food Science		
J. Appleman, Research Assistant	100	July '75-present
Sampathiengar Kanthamani, Research Asst.	50	July '75-present
T. A. McCune, Research Assistant	100	July '75-present
D. Pressner, Research Assistant	50	August '74-April '75
Donna Rosborough, Research Assistant	100	April '73-July '75
Margaret Tucker, Secretary	50	August '75-present
Plant Pathology		
G. R. Bowers, Jr., Research Assistant	25	August '75-present
O. D. Dhingra, Research Assistant	100	February '75-May '75
F. D. Tenne, Research Assistant	50	June '75-March '76
P. Thongmeearkom, Research Assistant	25	May '75-present
Vicki Toews, Secretary	50	June '75-present

APPENDIX 1-A

SOYBEAN VARIETY DEVELOPMENT

Accomplishments

The International Soybean Variety Evaluation Experiment (ISVEX) results from 1973 were published and distributed to interested parties. The ISVEX-2 was analyzed and is being prepared for publication. Data were returned from 63% of the cooperating sites. Eighty-six of the 136 sites and 39 of the 60 cooperating countries returned valid data (Table 1). Seed samples were returned from 61 sites in 29 countries for protein and oil analyses.

Summary of Results

1. Second ISVEX. During the second ISVEX the same 15 cultivars included in the first ISVEX were tested at each site. Environmental zones (Table 2) of 10° latitude and 500 meters were used as a broad classification of the environments where the soybeans were tested. Zones I and IV are emphasized since they contained the greatest number of sites. The mean yield of 37 sites in zone I was 2260 kg/ha (34 bu/A). The highest reported yield for zone I was 5465 kg/ha (81 bu/A) for Jupiter at Maracay, Venezuela. Zone IV, which differs from zone I by 10° latitude, had a mean yield of 1928 kg/ha (29 bu/A) and a mean of the highest yielding entry at each site of 2370 kg/ha (35 bu/A). The highest reported yield from zone IV was 4392 kg/ha (65 bu/A) at Abapo-Izozog, Bolivia. Zones I and IV were represented by 37 and 21 sites, respectively. Table 3 shows the cultivars in zones I and IV which were most consistent for high yield. The same entries yielded high in both zones but their rank was different. No other zone was represented by more than six sites. In addition to those mentioned above, the following countries reported maximum yields greater than 4000 kg/ha (59 bu/A): Ecuador, Guyana, Iran, Nepal, Pakistan, and Sri Lanka.

The mean number of days to flower were 30 and 34 for zones I and IV, respectively. Mean days to maturity were 94 and 98 for the same zones. Most cultivars tested are sensitive to the environmental differences of the tropics which have resulted in earlier flowering and maturity. Plant height is also reduced in the tropics. The mean plant height was 45 and 48 cm for zones I and IV, respectively. The shorter daylength of zone I is the main factor responsible for early flowering, early maturity and less plant height than zone IV. However, grain yield and seed size were greater in zone I than zone IV.

Combined analyses were made across sites within geographical regions when five or more sites were available in a zone. Six sites in zone I for Africa produced a mean yield of 1325 kg/ha (20 bu/A). The highest yielding cultivar was Bossier, which produced 1782 kg/ha (26 bu/A). Improved Pelican, Davis and Hardee produced yields which were not significantly less than Bossier. Days to flower ranged from 32 to 36 and days to maturity ranged from 94 to 97 days for those four cultivars. Hardee was the shortest of the four cultivars at 28 cm, and Improved Pelican was the tallest at 63 cm.

In Asia, 19 sites in zone I tested ISVEX-2. The mean yield for all cultivars was 1862 kg/ha (28 bu/A). Davis produced the highest yield of 2138 kg/ha (32 bu/A) followed by Bossier, Hardee and Improved Pelican. Davis had a plant height of 30 cm and was earlier and shorter than the other three cultivars. Bossier had the longest flowering and maturity period of 33 days and 95 days, respectively. Improved Pelican produced the tallest plants at 62 cm.

Mesoamerica was represented by 13 sites in zone IV. Bossier was the highest yielding cultivar at 2425 kg/ha (36 bu/A) compared to a mean for all cultivars of 2181 kg/ha (32 bu/A). Jupiter, Davis, Williams, Clark 63, Hampton 266A and Bragg produced yields not significantly different than Bossier. Days to flower ranged from 30 days for Clark 63 to 42 days for Jupiter among those seven cultivars. Williams matured in 92 days and Jupiter required 124 days to mature. Plant height ranged from 36 cm for Hampton 266A to 72 cm for Jupiter.

South America had eight sites in zone I and five sites in Bolivia representing zone IV. For zone I Jupiter was the highest yielding cultivar with 3359 kg/ha (50 bu/A) compared to a mean of 2435 kg/ha (36 bu/A). Bossier produced a yield of 3152 kg/ha (47 bu/A) which was not statistically different from Jupiter. Days to flower were 37 and 36 for Jupiter and Bossier, respectively. However, Jupiter required 107 days to mature compared to only 95 for Bossier. Jupiter was also taller than Bossier with 73 cm compared to 52 cm, respectively.

Jupiter was also the highest yielding cultivar at the zone IV sites in Bolivia. Jupiter yielded 2996 kg/ha (45 bu/A) compared to a mean of 2234 kg/ha (33 bu/A). Yields of Bossier and Davis were not significantly less than Jupiter. These three varieties flowered between 39 and 43 days and matured between 101 and 120 days. Plant height ranged from 37 cm for Davis to 68 cm for Jupiter.

The range in latitude for test sites was from 27° S in Swaziland to 40° N in Spain. Altitude ranged from sea level in Ivory Coast to 1850 m in Ethiopia. However, 58 sites were located within 20° of the equator and less than 500 m altitude (Table 2).

2. Third ISVEX. During 1975 the third ISVEX was distributed to 257 sites in 90 countries (Table 4). Two sets of cultivars were distributed. The late maturity set included 15 entries from maturity groups III through IX. The early set included 15 entries from maturity groups 00 through V. Groups III, IV and V were represented in both sets. Latitude and altitude of the site were the factors considered when determining which set of entries were tested. Data have been received from 61 sites in 36 countries which tested ISVEX-3.

3. Fourth ISVEX. Six sets of cultivars have been distributed during 1976. The sets are organized by environmental zones utilizing cultivars which have performed well in past experiments and new entries with potential in each environment. Cultivars Calland, Williams, Woodworth, Clark 63 and Forrest are included in all six sets. As of May 1, 1976, ISVEX-4 had been requested by 181 sites in 50 countries and requests are received regularly.

Discussion

The high grain yield achieved in experimental plots with good management indicates that soybeans do have production potential in many new areas of the world. Temperate environment cultivars do not produce ideal plant types when grown in the tropics, but extensive breeding programs can improve these characteristics. Farmers would not be expected to achieve such high yields on large fields, but proper management and cultivar selection will result in acceptable yields.

The ISVEX has answered some questions about the adaptability of temperate zone cultivars in the tropics; however, additional questions have been raised. For example, what is the maximum altitude at which soybeans can be grown and what environmental variables limit growth at high altitudes? To study these questions the ISVEX-4 is being tested at eight sites in Colombia and Ecuador which range in altitude from 17 m to 2610 m. The same cultivars will be tested at each site during each season (two seasons per year for all but one site) for the next two years. In addition to the agronomic variables measured for all ISVEX tests, the following environmental measurements will be made: solar radiation, evaporation, maximum and minimum temperature, and rainfall. All sites selected were located within 5° of the equator to reduce day length variation.

Another question often raised is, why do the introduced cultivars produce less when seed is produced in the tropics or subtropics than when the seed is sent from the U.S.? To study this problem a Seed Quality Study has been designed for testing at four international sites. Fungicides will be used to control certain pathogens and yield will be compared to the control plots. Seed from the treated and untreated plots will be used the next seasons to study the drift in yield potential. The study will begin in 1976 and continue for three years with check materials from the U.S. each year.

New material is available for evaluation in the ISVEX, but must be screened to identify potential areas of adaptation. The Soybean Preliminary Observation Trial (SPOT) was designed to serve as a screening test for new material. In 1976, the SPOT is being conducted at six sites which represent environments where the ISVEX has been grown. The cooperators were selected because of their outstanding performance with previous experiments. SPOT-1 includes 14 cultivars which include two check entries which are also tested in ISVEX. The cultivars represent material from five countries and range from small seeded types to a large seeded vegetable type.

SPOT-1 is being tested in Ecuador, India, the Philippines, Puerto Rico, Rhodesia, and Sri Lanka during 1976. The cultivars being tested are:

CH-3	Buffalo
M-79	Hardee - LS
M-98	Jupiter
M-216	Kanrich
SJ-1	Oribi
SJ-2	Rhosa
Bossier	Santa Rosa

The SPOT was developed in cooperation with the 211(d) activities of the University of Illinois and the University of Puerto Rico.

Slight changes are made annually in the ISVEX techniques to more efficiently collect reliable information. Cultivars are selected each year for different environmental zones. This procedure results in a gradual improvement in the cultivars available for commercial production in each zone.

Joint experiments have been organized with the International Institute of Tropical Agriculture (IITA) and The Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA) to eliminate duplication of testing the same material at the same research stations. The INTSOY/IITA experiment is being tested at African sites between 20° N and 20° S latitudes. INTSOY provides eight entries, the instructions, data book, and inoculant. IITA provide the remaining eight entries.

A similar arrangement was made for the INTSOY/SEARCA experiment for testing early cultivars at locations in Southeast Asia.

TABLE 1. Sites which completed the second International Soybean Variety Evaluation Experiment (ISVEX-2).

Region	Country	Site	Protein & Oil Analysis
Africa	Angola	Nova Lisboa	x
	Cameroon	Wum	x
	Egypt	Bahteem	x
		Seds	x
	Ethiopia	Awassa	
		Bako	
		Debra Zeit	
		Jimma	x
	Ghana	Kwadaso	x
		Legon	
	Ivory Coast	Abidjan	
		Dekokaka	
		N'Dakro	
	Nigeria	Kadawa	
	Rhodesia	Salisbury	
	Sierra Leone	Njala	
	Swaziland	Malkerns	
	Zambia	Kitwe	
Asia	Afghanistan	Baghlan	
	India	Pantnagar	x
	Indonesia	Muneng	x
	Malaysia	Serdany	x
	Nepal	Khumaltar	x
	Pakistan	Parachinar	x
		Sarai Naurang	
		Swat	x
		Tandojam	
		Tarnab	
	Philippines	La Carlota	x
		Los Banos	x

TABLE 1 (Continued)

Region	Country	Site	Protein & Oil Analysis
	Sri Lanka	Alutharama*	x
		Angunukolapalessa*	x
		Bandirippuwa*	x
		Gannoruwa*	x
		Kilinochchi	x
		Maskeliya	
		Maha Illuppallama*	x
		Puttalam*	x
		Ratmalagara*	x
		Thirunelvely	x
	Taiwan	Shanhua	x
	Thailand	Chiang Mai	
		Khon Kaen	
		Maejo	x
Europe	Spain	El Encin	x
Mesoamerica	Costa Rica	Las Juntas	
		Taboga	
	Dominican Republic	Santiago	x
	El Salvador	Santa Cruz Porrillo	
	Mexico	Apatzingan	x
		Uxmal	
	Panama	Tocuman	x
	Puerto Rico	Isabela*	x
		Lajas	
		Mayaguez	
	Trinidad	Port-of-Spain*	x
Middle East	Iran	Karaj	x
	Israel	Bet Dagen	x
	Jordan	Wadi Dhuleil	
	Lebanon	Bega'a	x
	Saudi Arabia	Dirab	x
		Wadi Gizan	x
South America	Bolivia	Abapo-Izozog	x
		Palometillas	x

TABLE 1 (Continued)

Region	Country	Site	Protein & Oil Analysis
		Portachuelo	x
		Santa Cruz*	x
		Villa Montes	x
	Colombia	Ibague	x
		Motilonia	x
	Ecuador	Boliche	x
		Pichilingue	x
		Portoviejo	x
	Guyana	Ebini	x
		Mon Repos	x
	Venezuela	Maracay	x

* More than one experiment during year

TABLE 2. Description of environmental zones for the second International Soybean Variety Evaluation Experiment.

Zone	Latitude	Altitude	Number of Sites
I	≤ *10°59'	≤ *500	37
II	≤ *10°59'	501 - 1000	1
III	≤ *10°59'	>**1000	5
IV	11° - 20°59'	≤ *500	21
V	11° - 20°59'	501 - 1000	0
VI	11° - 20°59'	>**1000	3
VII	21° - 30°59'	≤ *500	6
VIII	21° - 30°59'	501 - 1000	2
IX	21° - 30°59'	> **1000	1
X	31° - 40°59'	≤ *500	3
XI	31° - 40°59'	501 - 1000	5
XII	31° - 40°59'	> **1000	2

*≤ = less than or equal to.

**> = greater than.

TABLE 3. Mean Rank of cultivars for high yield within zones I and IV for the second International Soybean Variety Evaluation Experiment.

Zone I	Zone IV
(37 sites)	(21 sites)
Davis	Jupiter
Bossier	Bossier
Improved Pelican	Calland
Jupiter	Improved Pelican
Hardee	Davis
Calland	Hardee

List of International Soybean Variety Evaluation

Experiment (ISVEX)-No. 3 Cooperators for 1975

Region	Country	Name	Address
AFRICA	Algeria	The Officer-in-Charge	Station Experimentale I.N.R.A.A. Khemis-Miliana El-Asman, ALGERIA
	Burundi	Mr. E. Sebatutsi	Director General ISABU B.P. 795 Bujumbura, BURUNDI
	Cameroon	Dr. H. D. Drechsler	Director Wum Area Development Authority Wum via Bamenda P.O. Box 13 CAMEROON
		Monsieur le Directeur de l' IRAT/Cameroun	Boite Postale 2 123 Yaounde-Messa CAMEROON
	Central Africa	Mr. Emilein Lefort	Project Manager FAO, CAF/72/006 c/o Resident Representative UNDP P.O. Box 872 Bangui, REPUBLIC OF CENTRAL AFRICA
	Chad	Dr. Bernhard Kraft	Ing. Agr. SWISSAID B.P. 1113 N'Djamena, CHAD
	Congo	Ing. Ivetic Obrad	Expert de la FAO BT. 3 Lekana Brazzaville, CONGO
	Dahomey	Mr. R. Dumont	IRAT BP. 155 Parakou, DAHOMEY
	Egypt	Dr. Ali Abdel-Aziz	Head, Grain Legume Research Section Field Crops Research Institute Agricultural Research Centre Giza, EGYPT
	Ethiopia	Mr. Abdurahman Ali	Institute of Agricultural Research Bako Research Station P.O. Box 3 Bako, ETHIOPIA

Region	Country	Name	Address
AFRICA	Ethiopia	Mr. Zewudu Oumer	Agronomist Awassa Experiment Station P.O. Box 16 Awassa, Sidamo, ETHIOPIA
	Gambia	Dr. L. J. Marenah	Director of Agriculture Department of Agriculture Cape St. Mary THE GAMBIA
	Ghana	Dr. Bob Dadson	Department of Crop Science Faculty of Agriculture University of Ghana Legon, GHANA
		Mr. Hector Mercer-Quarshie	Crops Research Institute P.O. Box 3785 Kumasi, GHANA
	Ivory Coast	Dr. Assa Ayemou	B. P. 4322 Abidjan, IVORY COAST
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APPENDIX I-B

SOYBEAN VARIETY DEVELOPMENT

Seed Quality Studies

Accomplishments

The effect of storage conditions and environment during maturation on soybean seed quality and crop performance were studied by a Ph.D. candidate, from India, over a two- and one-half-year period. The Ph.D. dissertation has now been completed and articles are being prepared for publication.

Summary of Results

A series of experiments to determine specific changes in viability and vigor of soybeans as influenced by environmental conditions during maturation and subsequent storage were conducted in Urbana. The effect of seed source and planting date on seedling emergence, yield and subsequent seed viability was also determined. The main objectives of the experiments were to determine (1) the effect of high humidity during seed maturation on seed vigor and viability, (2) the effect of moisture (13, 10 and 7 percent), temperature (35°, 25°, and 3°C), and container (1, 5 and 8-mil thick polyethylene and tin) on soybean seed viability and vigor in storage, and (3) the effect of seed source and planting date on field emergence, yield and seed quality.

Seed viability and vigor were impaired by humidity treatments during the maturation stage of growth. The high incidence of Phomopsis was associated with a decline in seed vigor before physiological maturity. Williams cultivar tolerated adverse high humid conditions and had better seed quality than cultivars of comparable maturity, i.e., Wayne and Woodworth. The humidity system designed for creating humid conditions can be used in screening soybean lines for resistance to field weathering under humid conditions during the maturation period.

The storage environments simulated in the present study included conditions similar to those encountered during the premonsoon season of central India. At 35°C, seeds with an initial moisture content of 13 percent stored in 8 and 5 mil thick polyethylene and tin containers lost viability and vigor in 8 weeks. At this temperature seeds with 7 percent initial seed moisture did not lose viability and vigor as fast as seeds with 10 and 13 percent initial moisture. High moisture combined with high temperature increased liberation of CO_2 from stored seed. This was indicative of fungal growth and the high rate of respiration in seeds of higher moisture content. At 25°C, seeds stored with 7 and 10 percent moisture in all containers maintained viability and vigor for 16 weeks. At 3°C, seeds maintained viability above 80 percent regardless of initial seed moisture and type of container. Seed lots stored at 13 percent moisture at all storage temperatures had a greater percentage of seeds infected with bacteria (probably Bacillus sp) than those stored at 10 and 7 percent. Also, the percentage of seeds (at 13 percent moisture) yielding bacteria was greater at 35°C than at 3°C. At 25°C

and 35°C storage temperatures, the percentage of seeds infected with fungi (Aspergillus sp) increased with time at 13 percent seed moisture in tin and 8 mil polyethylene containers. The Bacillus and Aspergillus sp were associated with the severe decline in vigor of seeds stored at high temperature and high moisture. The multiple regression equation

$\hat{y} = a + b_1x_1 + b_2x_1^2 + b_3x_2 + b_4x_2^2 + b_5x_1x_2$ was found to be best for estimating viability where x_1 is the storage temperature and x_2 is initial seed moisture.

Seed production location had considerable influence on seed viability and vigor of soybean cultivars. Seedlots from southern Illinois had a higher percentage of fungal infection than seedlots from central and northern Illinois. Williams cultivar had few infected seeds at all locations in most years. Seedlots from the southern location produced a lower percentage of seedlings in the field than seedlots from northern and central locations. Differences in seed quality attributed among seed sources had no significant effect on yield, when stands were adjusted to uniform densities.

Discussion

These results have far reaching implications relative to assisting in solving seed quality and storage problems in the tropics and subtropics.

The results form the backbone for additional seed quality trials such as the one initiated in 1976. This trial was organized by INTSOY as one of several multidisciplinary efforts to improve overall soybean seed quality. Its basic objectives are to (1) monitor seed quality of introduced, early maturing cultivars in different tropical environments, (2) determine the effects of variations in seed quality on stand establishment and productivity of the subsequent soybean crop and (3) evaluate the usefulness of a foliar applied fungicide in improving soybean seed quality in the tropics.

APPENDIX I-C

SOYBEAN VARIETY DEVELOPMENT

Screening for Daylength Sensitivity

Accomplishments

In wheat and rice breeding programs for tropical and subtropical environments, considerable progress has been made by the development of photoperiod insensitive (day neutral) genotypes. The soybean is highly photosensitive and is a short-day plant; that is, most genotypes will flower more rapidly under short-day conditions than under longer photoperiods. Varieties adapted to higher latitudes flower and mature more rapidly in the lower latitudes, while flowering and maturity of genotypes adapted to lower latitudes are delayed if they are grown in higher latitudes. If day neutral soybean genotypes can be found and/or developed, they should be a valuable asset for breeding programs, especially at low latitudes. A highly heritable source of insensitivity to daylength would greatly facilitate the transfer of traits from temperate to tropical varieties.

Summary of Results

Day neutral soybean genotypes have been reported in some of the earliest maturing lines (maturity groups 00 to 0). INTSOY has recently field screened (at Urbana, Illinois and Isabela, Puerto Rico) most accessions from maturity Group III of the USDA soybean germplasm collection by extending the photoperiod to 24 hours per day by use of artificial lighting. Of 515 genotypes screened, one line, PI 317.334B (Kitami Shiro), was identified as possessing unique photoperiod insensitive properties which may be useful in the breeding of soybean lines with wide latitudinal adaptation. A few other genotypes were found to be partially insensitive. A wide range in sensitivity for flowering was indicated. Contrary to the expectation of some researchers, all genotypes eventually flowered under the extended daylength. Maturity appears to be more affected by photoperiod than flowering, a fact sometimes not considered in photoperiodic screening experiments. A soybean genotype may exhibit a different level of photosensitivity for flowering than for maturity. Differences in flowering and maturity caused by natural and extended daylength were greater in Puerto Rico than in Illinois.

Operational Significance

It remains to be seen how valuable this apparent photoperiod insensitivity of Kitami Shiro will prove to be.

Side Effects of the Work

This research is helping to determine relationships among flowering, maturity and photosensitivity. The fact that flowering and maturity were not completely inhibited but only delayed (except for Kitami Shiro) is of considerable interest.

Research Design

In Puerto Rico and Urbana, Illinois, plant breeders have made a series of crosses using the insensitive plant introduction and a diverse group of cultivars as parents to study the inheritance of insensitivity and its genetic relationship with other characters, especially maturity. This insensitivity will be of limited value if it cannot be transferred into varieties that are later maturing and higher yielding than Kitami Shiro.

APPENDIX II

INSECT CONTROL AND ENTOMOLOGICAL STUDIES

Accomplishments

1. Service oriented

a. Soybean Insect Research Information Center (SIRIC). During the past several years SIRIC has been partially supported by INTSOY. It was INTSOY in fact, which provided the initial financing of the concept that evolved into SIRIC.

SIRIC is a supporting unit coordinated by and directly associated with the soybean research program of the Illinois Natural History Survey and the University of Illinois. The information center presently contains over 13,000 titles covering the literature of insects associated with soybeans and insect borne diseases of soybeans. Bibliographic references are stored on magnetic tapes using FORTRAN IV language for retrieval on an IBM 360/75. Programs related to this computerized storage include routine checking of input data, updating of current data, entire or partial listing of the documents and most importantly, searching of literature according to specific parameters.

The Center aims to serve the immediate and long-range needs of researchers at the University of Illinois (INTSOY) and the Illinois Natural History Survey as well as those working in other institutions. Service, primarily in the form of a computer search, is provided on a personal level to any interested researcher.

Searches are formulated within particular subject parameters. To this end, a hierarchical code-word description thesaurus has been created. The Hierarchical Code Descriptors Thesaurus is a key part of the storage and retrieval system. Use of controlled vocabulary allows SIRIC personnel to assign codes for information contained in the documents collected by SIRIC. These codes are used in the process of retrieving the pertinent documents in a literature search. The rapid growth of the literature of soybean-associated arthropods makes it necessary to continually add new species to the taxonomic section of the thesaurus. Because this literature is becoming increasingly complex the same expansion process is followed in all other sections of the thesaurus.

Like any other data base, SIRIC is unlikely to provide complete coverage on retrospective literature. This means that for many subjects the computer search is only a beginning which must be complemented by a manual search. It provides initial leads to the literature of the subject being investigated in terms of authors active in the field, titles of journals where related articles could be found and other such clues.

As an added service SIRIC provides complete coverage or currency of the literature involved in documenting new research.

Users of SIRIC are frequently impressed with the large number of foreign citations retrieved. SIRIC maintains close working relationships with researchers abroad and as a result of this cooperation it receives copies of articles published in soybean producing countries. These articles are often published in foreign journals not frequently located in U.S. libraries. This places SIRIC as a valuable depository of foreign material.

Exhaustive searches have been made on some species of key importance. As a consequence, bibliographies have been published on the Mexican bean beetle, Epilachna varivestis; southern green stink bug Nezara viridula; bean leaf beetles, Cerotoma trifurcata and C. ruficornis; velvetbean caterpillar, Anticarsia gemmatalis; northern corn rootworm, Diabrotica longicornis; and western corn rootworm, D. virgifera; and the spotted alfalfa aphid, Therioaphis maculata. Currently SIRIC is working on a bibliography of the the Heliothis spp. complex. Heliothis zea and Heliothis virescens are major pests of corn, cotton, tobacco, soybeans and are considered the pests of greatest economic importance in the western hemisphere. SIRIC is cooperating with the alfalfa project to put together bibliographies on the pea aphid, Acyrthosiphon pisum (Harris), and the potato leafhopper, Empoasca fabae (Harris). Although funded by alfalfa monies, these pests are important to soybean entomology.

In depth searches on the following 24 species of important soybean insects is routine:

Soybean Pests

Acrosternum hilare
Bemisia tabaci
Colaspis brunnea
Diabrotica longicornis
Diabrotica virgifera
Empoasca fabae
Heliothis virescens
Lygus lineolaris
Plathypena scabra
Sericothrips variabilis
Anticarsia gemmatalis
Cerotoma (all species)
Colias eurytheme
Diabrotica undecimpunctata howardi
Elasmopalpus lignosellus
Epilachna varivestis
Heliothis zea
Nezara viridula
Pseudoplusia includens
Tetranychus urticae

Natural Enemies

Geocoris (all species)
Orius (all species)
Nabis (all species)
Podisus maculiventris

Services provided by SIRIC have increased over the years. For instance, in the 1974-75 year, 42 requests were filled (19 for staff, 7 from U.S. researchers, and 16 from researchers outside the U.S.). In 1975-76, 72 requests were processed (51 staff, 6 U.S., 15 outside the U.S.). The service has proved exceedingly valuable to soybean researchers the world over.

b. The International Reference Collection of Soybean Arthropods (IRCSA). INTSOY provided the monies needed to initiate IRCSA and has supported it over the years. Currently, IRCSA is funded primarily through the domestic soybean program.

The International Reference Collection of Soybean Arthropods is a specialized resource base for researchers involved in many aspects of soybean protection. It serves as a depository, not only for specimens of soybean arthropods, but also for associated field data. It is exceedingly important to persons and institutions developing new soybean research programs. It is also extremely valuable to researchers with well-established programs.

The concept of an international soybean arthropod data base was developed at the University of Illinois and the Illinois Natural History Survey in 1968 (Kogan and Luckmann, 1971). In 1969 an international reference collection of soybean arthropods was started (Godfrey, 1974b) which directly contributed toward this goal. A collection of this type is innovative and unique because it represents the first development of an international reference collection of arthropods of any single agricultural crop.

The basic goal of IRCSA is to support and assist in the development of soybean insect pest management programs through the development of a soybean arthropods resource base. The specific objectives of IRCSA are:

(1) identifying specific arthropods collected in soybean fields;
(2) processing field samples for faunal studies;
(3) providing regional synoptic reference collections of soybean arthropods to national and international institutions;
(4) providing names and addresses of soybean entomologists to new researchers as potential contacts and collaborators;
(5) determining the distribution of major soybean pests, vectors of soybean diseases, and natural enemies;
(6) determining the phenology and relative seasonal abundance of soybean arthropods for pest-management studies;
(7) associating predatory and parasitic arthropods with the pest species.

Currently, IRCSA contains over 100,000 specimens including 800 species from 25 countries. IRCSA has the capability of providing reliable identifications for 80% of North American soybean arthropods and 50% of South American species. As more specimens are determined by experts and placed in IRCSA, the number of reliable identifications possible by IRCSA staff will increase.

Linkages have been established with many United States institutions, national institutions from LDCs and international organizations. There have been increasing demands for IRCSA services by LDCs and United States institutions. The resource information contained in IRCSA has begun to be utilized by and incorpoated into soybean insect pest management programs.

c. Outreach. Outreach, service-oriented activities include publications and "in-country" advisory activity. Some of these items will be presented below under "research" activities. The bibliographies of soybean arthropod pests (mentioned under SIRIC) have helped many researchers and extension personnel in LDCs by allowing them access to literature of certain major pests (e.g. *Nezara viridula*). The compilation of "Selected Literature of Soybean Entomology" edited by G. L. Godfrey (1974a) has helped workers

overseas get an idea of soybean arthropod research in handy packet form. Already, over 1000 of these booklets have been distributed out of 1200 printed (including a second printing). Papers by Kogan (1974) and Godfrey (1974b) in the proceedings of the workshop on soybeans for tropical and subtropical conditions helped greatly in getting across ideas relevant to soybean pest management and IRCSA, respectively, to peoples in LDCs. Turnipseed and Kogan (1975) in an Annual Review article brought the status of knowledge on soybean entomology up to date. Several entomologists presented papers at the First World Soybean Conference on various aspects of soybean entomology. They too added to and summarized the expanding literature of soybean arthropods so important in technology transfer. Recently, Heinrichs (1976a, 1976b); Irwin (1976); Irwin and Price (1976); Kobayashi (1976); Kogan (1976b, 1976c); Pisit (1976); Rejesus (1976), and Rose (1976) contributed entomological papers to "Expanding the Use of Soybeans, a Conference for Asia and Oceania", sponsored in part by INTSOY. Kogan and Luckmann (1976) have put together a guideline for soybean insect pest management in Illinois. Kogan et al. (1976) has expanded on this in Brasil.

M. E. Irwin organized the entomology component of the first soybean production training course, held at UIUC during the summer of 1975. The entomology component was oriented to emphasize an in-depth understanding of insect pest management. This component included nearly 50 contact hours by a total of 16 entomologists from UIUC and Illinois Natural History Survey.

2. Research Oriented Accomplishments

a. Rearing, sampling, and mechanisms of observing movement of soybean insects (cooperative work with Dr. M. Kogan, Entomologist, Illinois Natural History Survey).

Rearing methodologies were developed for the soybean thrips, *Sericothrips variabilis*, and the bean leaf beetle, *Cerotoma trifurcata*. These are both potential vectors of viruses and the latter is a soybean pest in North America.

Sampling procedures have been developed for aphids, thrips, and most soybean pests and their major predator species in North America. By extension, these methodologies will prove valuable on pests, vectors and natural enemies in other soybean growing areas of the world. A special set of cylindrical sticky traps was developed to detect movement activity of of small soybean insects, especially in relation to wind direction. Of special note were several species of thrips and aphids, *Orius*, and many species of parasitoids, especially elusive egg parasitoids.

A marking system using RbCl translocated into plants and from them into insects was adopted to study both movement patterns of pests and trophic interactions in the soybean ecosystem. Rb^+ was chosen because it was not radioactive, it moved easily into plants and animals, did not upset the ecosystem (as would be done with dye markers), and the method of detection (atomic absorption spectrometry) was very precise, the Rb^+ being detectable at extremely low concentrations. Furthermore, background levels of Rb^+ are very low and Rb^+ physiologically replaces K^+ in plants and animals with little or no side effects.

An experiment was conducted within growth chambers to determine what level of RbCl needed to be added to the soil in order to clearly mark the plants, the herbivors and the carnivors. It was determined that 1000 ppm in the soil was adequate. Much material from that study still needs to be analyzed in order to determine where the Rb^+ concentrates during the various growth stages of the soybean plant.

In 1975, two 5 x 5 meter plots near Havana, Illinois were selected for Rb^+ treatment. The plots were carefully hand weeded and 30 ml of 1000 ppm solution of RbCl were applied to the base of each young plant within the restricted areas. During the growing season two plants from within and an equal number from without were collected per field, separated into various nodes and leaves, roots, pods and seeds, dried, digested in acids and run through an atomic absorption spectrometer (AAS). Results indicated that plants had been labeled two to ten fold above background (Fig. 1) and that insects which had fed on labeled plants contained more than twice background levels of Rb. When Rb-enriched pests were removed from a Rb-enriched soybean plant and allowed to feed on normal soybeans, most of the Rb left the pests after eight days. However, a detectable and significantly above background level of Rb seemed to remain with the pests for several weeks. This technique is highly specialized, but studies can be conducted in other parts of the world and analyzed in Urbana at a later date with no fear of altering the true Rb levels in plants or insects.

b. Pest Management Systems (cooperative work under the direction of Dr. M. Kogan). A published version of the guidelines for soybean pest management in Illinois is in preparation (Kogan and Luckmann 1976). This gives economic injury levels, seasonal abundance and identification guidelines for all potential pests of soybeans in Illinois.

A pilot pest management program was tested by Dr. M. Kogan during the 1974-75 season in two locations in Brasil. This program was carried out in collaboration with Merle Shepard and Sam Turnipseed, Clemson University, and two Brasilian institutions, the state supported IAPAR - in Paraná, and the industrial cooperative FECOTRIGO - in Río Grande do Sul. The program tested on large scale commercial operations some of the assumptions guiding our domestic pest management programs. In general the program was a success in both Brasilian locations. The following is a description of the program and a summary of the results.

Six commercial plantings were selected in the heart of the soybean growing region of northern Paraná, near Londrina, and three plantings in the main growing region of Río Grande do Sul (Fig. 2) were selected. Paired fields ranging from 10 to 30 ha each were selected. Each group of paired fields was of similar soil type, topography, and was planted on the same date, with seed of the same variety. One field of the pair was managed according to the prescription of the proposed program. The second field was treated following the farmer's traditional criteria. The managed fields will be referred to as IPM fields, and the other FT (or farmer's treatment) fields. The target species were the complex of lepidopterous defoliators consisting of: Anticarsia gemmatalis (the velvetbean caterpillar), Pseudoplusia includens (soybean looper), Plusia oo; and the complex of stink bugs, consisting mainly of Nezara viridula, Piezodorus guildinii, and Euschistus spp.

APPROXIMATE LEVELS OF Rb^+ IN SOYBEANS

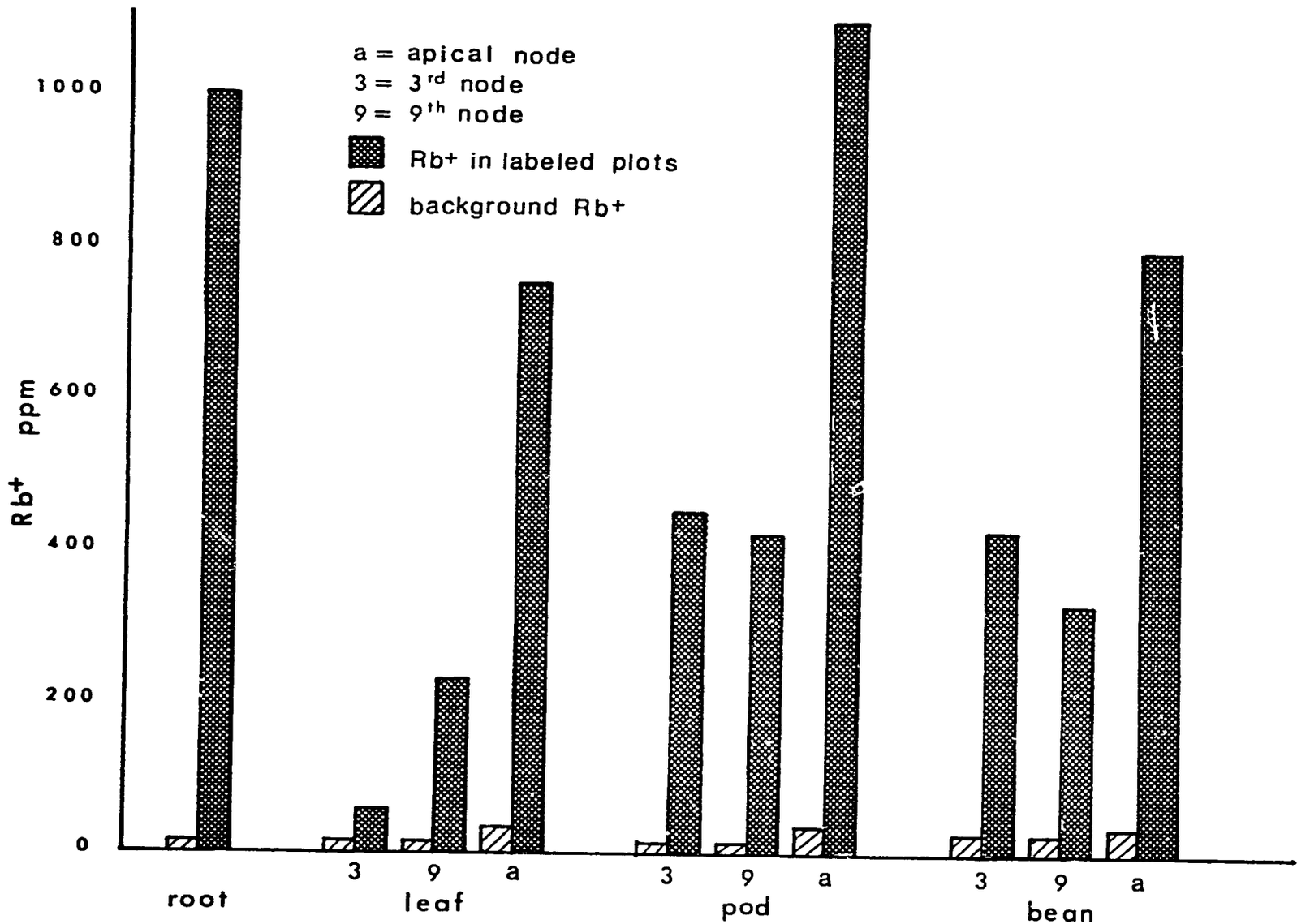


Fig. 1.

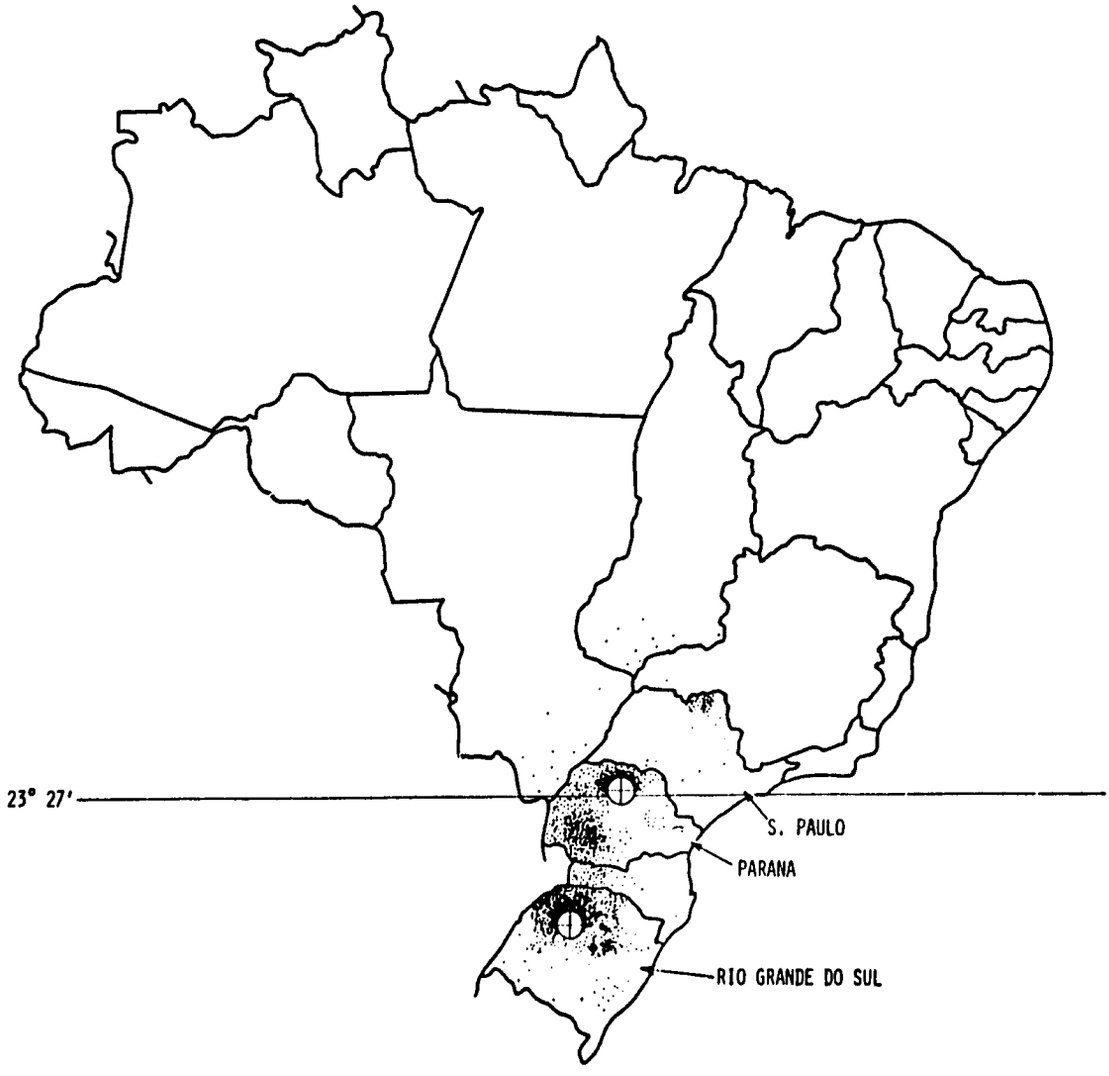


Fig. 2.

THRESHOLD CHART

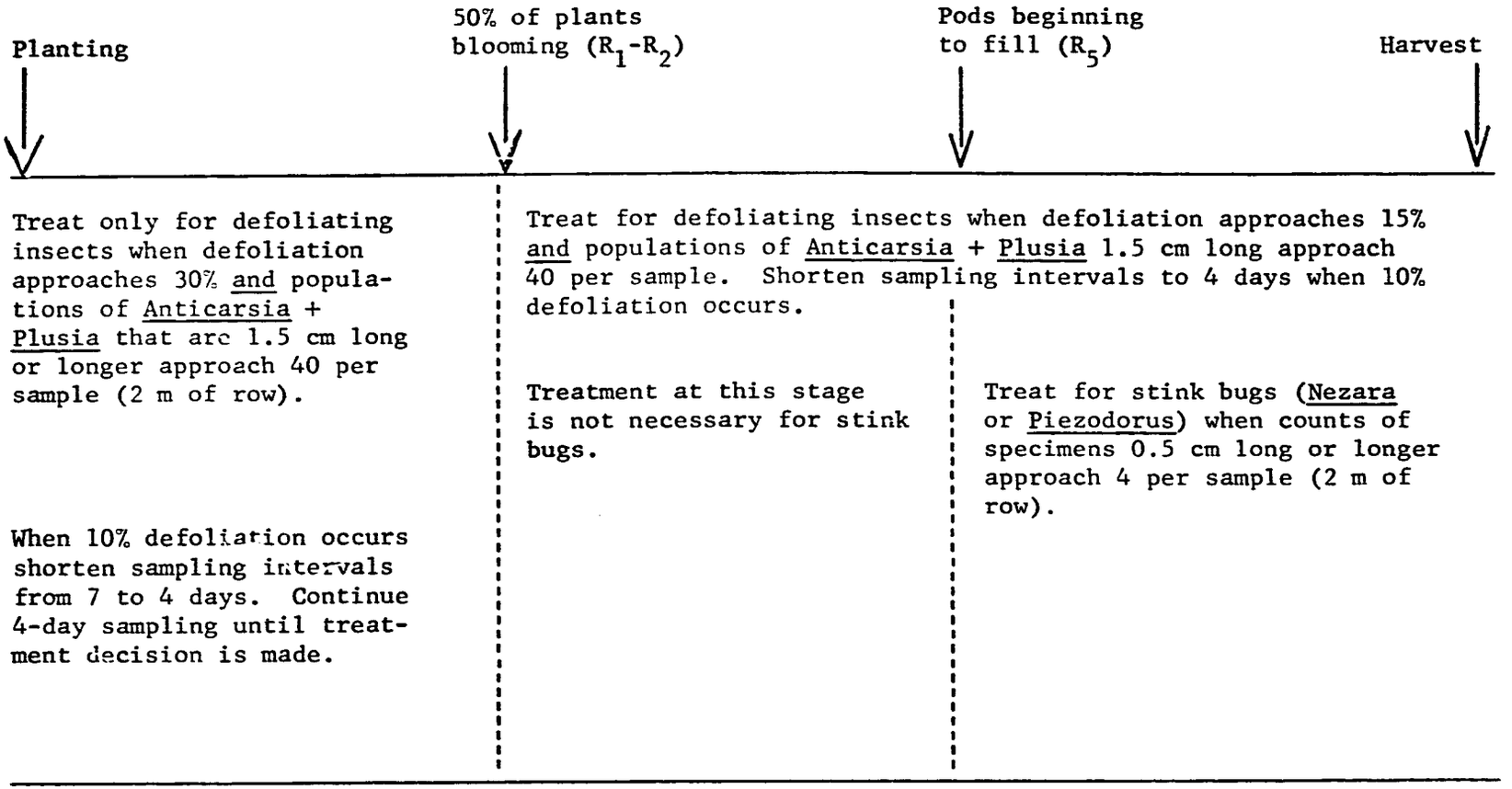


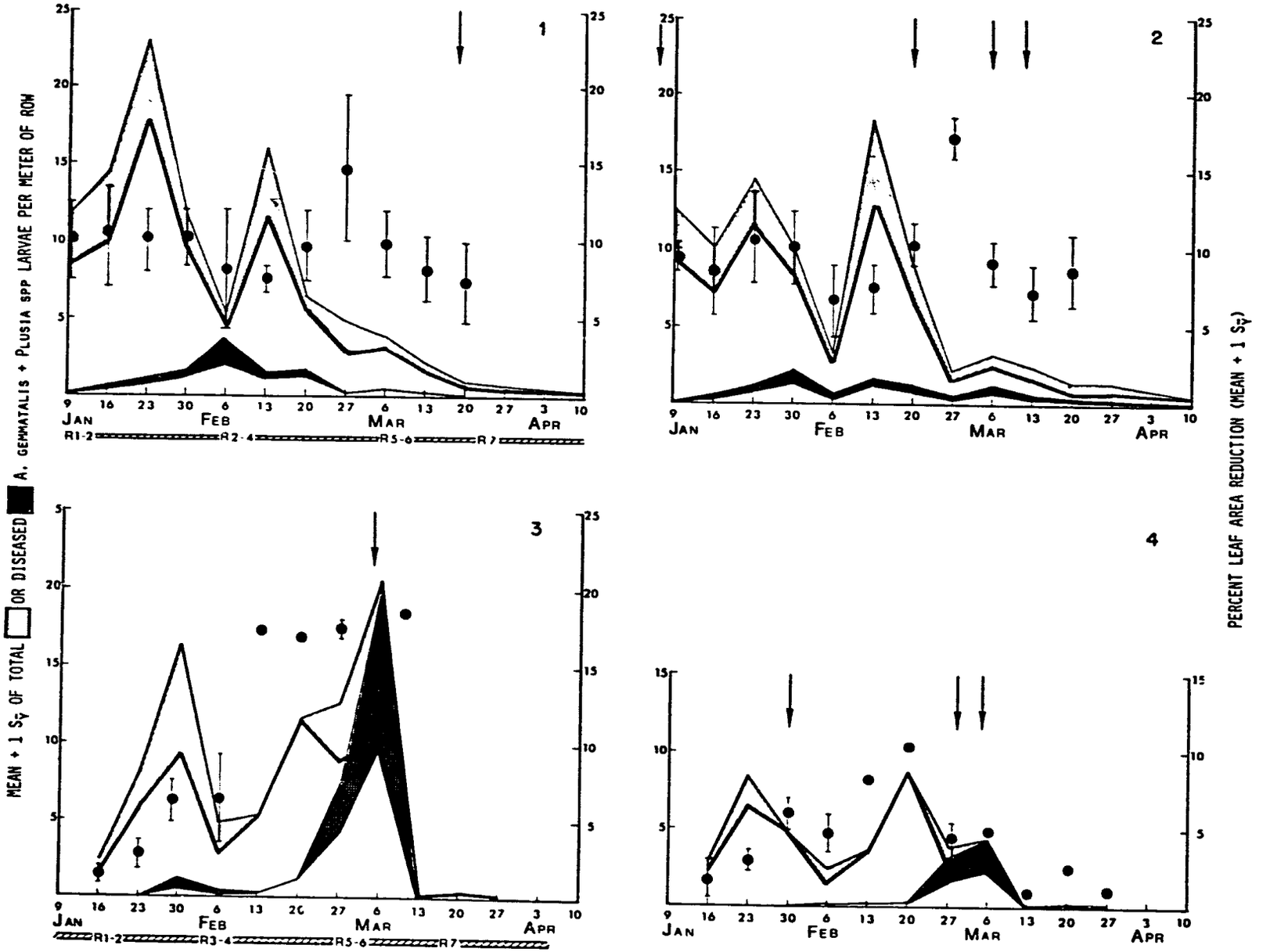
Fig. 3. Economic damage thresholds used in the pilot pest management program. Damage thresholds refer to criteria based on a combination of population levels and damage (defoliation) levels.

Fig. 4. Suggested chemicals and dosages for use in the pilot pest management program. Rates indicated have the least detrimental effect on beneficial insects.

Insect*	Preferred insecticide	Rate a. i. (kg/ha)	Alternate insecticides	Rate a. i. (kg/ha)
Anticarsia	carbaryl	0.3	methyl parathion	0.3
			methomyl	0.2
			monocrotophos	0.2
Plusia	methomyl	0.5	monocrotophos	0.5
Stink bugs	methyl parathion	0.6	monocrotophos	0.5

* Use preferred insecticide unless high populations of other pests are present. For mixed populations of Anticarsia and Plusia, use methomyl at 0.5. For mixed populations of Anticarsia and stink bugs, use methyl parathion at 0.6. For mixed populations of all 3 insects, use monocrotophos at 0.5.

Figs. 5-8. Summary of the pilot pest management program in Brazil, 1975. Paraná data are means of six fields; 5. IPM fields and 6. FT fields. Río Grande do Sul data are means of three fields; 7. IPM fields, and 8. FT fields. Arrows indicate insecticidal application in any of the fields. Black dots with bars indicate percent defoliation.



A total of six sampling sites were selected in each field: four sites located at least 20 m into each extreme of the field, and two sites toward the center. The ground cloth method was the standard sampling procedure using a 1 m cloth upon which were shaken the two adjacent rows. Insects were counted in the field and recorded as early (I + II), mid (III + IV) or late instars (V + VI). The number of diseased (mainly N. rileyi infected) larvae was also recorded. Species of caterpillar were identified with confidence only at 3rd instar and older. Percent defoliation was determined by visual estimation and by using a sample of randomly collected leaflets that were then evaluated by comparison to pictures of leaflets displaying known percentages of removed leaf area. Treatment decisions were based on both pest population levels and percent defoliation, following Fig. 3. Control recommendations are shown in Fig. 4.

Figs. 5-8 summarize results obtained in Paraná and Río Grande do Sul. The light shaded curves represent total larval populations and the dark shaded curves represent Nomuraea infested larvae. The black dots show mean percent defoliation ± SD. Growth stages are indicated for the IPM fields only but they are the same for corresponding FT fields. The arrows indicate when an insecticidal treatment was made to any of the fields in the experimental set. In Paraná only one field was treated once (.16 treatments per field) for the control of stink bugs. The FT fields received 6 insecticidal applications during the season (1.0 treatment per field). Preventive treatments were made against defoliators. In Río Grande do Sul, one IPM field was treated once (.33 treatments per field) whereas the FT fields received 3 treatments (1.0 treatment per field). In both states the average farmer treats his fields 3 to 4 times per season if outbreaks do not occur necessitating additional sprays. However, in the FT fields decision to treat was obviously influenced by the decision regarding the IPM fields. Therefore, the number of treatments per field in both regions was atypically low. Even so the pest management program brought about an overall reduction in the treatment load of the order of 78 percent.

The pilot pest management program provided support to the basic premises upon which we base the Illinois IPM program. The adopted economic damage thresholds (combination of population level plus defoliation level), although high, did not pose any risk. No yield differences were recorded in the IPM fields versus the FT fields. The timing, number of samples per field and scouting procedures were adequate, although scouting time could be substantially reduced with better knowledge of the phenology of the pests. Incidence of the fungal diseases probably represent the major single mortality factor controlling populations of lepidopterous caterpillars. Development of a capability to predict epyzootics as well as to promote epyzootics will represent a substantial advancement in soybean pest management. This program proved beyond doubt the feasibility of adapting simple scouting procedures to developing integrated pest management programs even if knowledge of the phenology and population dynamics of key pests is not completely elucidated. Such programs can be adopted elsewhere as an interim procedure until more detailed information is gathered on the peculiarities of the local pest complexes.

c. Economic Injury Levels (cooperative work, under the direction of Dr. Marcos Kogan, Entomologist, Illinois Natural History Survey).

Economic injury levels give vital information in a pest management program. They set limits of damage tolerable by soybean plants at different developmental stages of the plant to various pest species. Thus, through scouting or supervision, pest populations can be monitored and damage levels not allowed to exceed tolerable limits. Papers on the concept and analyses of the components of economic injury levels were recently presented (Kogan 1975b, 1976a).

Realistic economic injury levels of pest populations have been calculated for many soybean pests in Illinois and elsewhere. They have been established for the soybean looper, Pseudoplusia includens, a major soybean pest in North, Central and South America under laboratory and caged field tests in Urbana. They have also been established for the potato leaf hopper, Empoasca fabae; the Mexican bean beetle, Epilachna varivestis; the bean leaf beetle, Cerotoma trifurcata; and others. These levels are very similar to levels obtained by researchers in other areas of the United States. Enough information is available from our data and economic injury level data of other researchers to give first approximations of damage thresholds for most defoliating soybean pests of western hemisphere and many for the eastern hemisphere. When tested for soybeans grown under tropical conditions, the levels established here proved reliable for first approximations (see above section on a pilot pest management program).

d. Host Plant Resistance (cooperative work, under the direction of Dr. Marcos Kogan, Entomologist, Illinois Natural History Survey).

Breeding lines (BC2 F5 Williams x 171451, and F4 or F5 of 'Williams', 'Wayne', 'Amsoy 71', 'Beeson', and 'Clark 63' x 171451 or 229358) were planted and evaluated in 1974 and 1975 in Maryland and in Indiana in cooperation with T. C. Elden (USDA-Beltsville, MD) and R. Edwards and G. Hallman (Purdue University, Indiana). Out of nearly 1,000 lines planted in 1974, 200 were selected for further screening in 1975. The same lines were evaluated in Illinois for agronomic characteristics. Preliminary results indicate about 80 percent recovery of resistance in BC2 F5 Williams x 171451, and better in some of the direct crosses.

These selections were mainly based on Mexican bean beetle feeding. However, at least in Indiana, there were other defoliators such as the red-legged grasshopper, Malanoplus femurrubrum, differential grasshopper, M. differentialis, and the green cloverworm to suggest that these lines may have multiple pest resistance. The breeding program continues under the coordination of Dr. R. L. Bernard, USDA-Regional Soybean Laboratory. Winter nurseries in southern Brasil were used in 1974-75. Marked differences in latitude resulted in inadequate growth of the Illinois lines. Selections made earlier by Dr. H. C. Minor from some of the original Illinois crosses resulted in late maturity group lines with considerable levels of resistance to the velvetbean caterpillar (Anticarsia gemmatalis). Observations made in the Brasilian nurseries on selections made in South Carolina and Mississippi raised some critical questions about the use of these winter nurseries. One major problem is the expression of resistance under various edaphic and climatic conditions, and the other is the behavior of local pest populations of the same species that may differ in their genetic make-ups (biological races).

All of the USDA Southern Regional Group VIII and Group IX germplasm has been evaluated for resistance to foliar attack by Cerotoma ruficornis at the Isabela Experiment Station, Puerto Rico, 46 days after planting and prior to insecticide application. The material was planted by Dr. E. H. Paschal II. The following germplasm showed the most resistance: variety Yelnanda, variety Yelredo, PIs 181,697; 259,543; 306,704. All resistant material was from Group VIII.

e. Virus-vector (cooperative work with INTSOY Virologist, Dr. R. M. Goodman).

1. Soybean Mosaic Virus (SMV). Soybean mosaic virus (SMV) is seed born and is transmitted from plant o plant by aphids in a non-persistant manner. Seed quality can be affected by this virus and about 20% of the germplasm tested has a high percentage of its seeds infected by SMV. This interferes with breeding programs, can lead to discounting on domestic and foreign markets, and can cause serious problems in developing countries where seed increase is conducted within the country.

A study of the epidemiology of this virus was begun in February 1975 in Puerto Rico. Sixteen 30 x 30 ft. plots were either inoculated with SMV once, twice or were not inoculated (checks). Two 1 x 1/2 ft. sticky traps were serviced twice weekly throughout the growing season and the aphids were separated and identified. Field spread of SMV in this experiment was moderate during February-May in Puerto Rico and seemed to be influenced by wind direction and proximity to 24 hour lights (these lights were in an adjacent field). Aphid abundance was never high, and although seven species were collected from the sticky traps, only one, Tetraneura nigriabdominalis (Sasaki), was collected throughout the growing season in relatively high numbers. The species collected and subsequently determined, via IRCSA, by Dr. L. M. Russel, USDA Systematic Entomology Laboratory were as follows:

Aphis craccivora Koch
Aphis gossypii Glover
Capitophorus hippophaes (Wlk.)
Myzus persicae (Sulz.)
Rhopalosiphum maidis (Fitch)
Schizaphis graminum (Rond.)
Tetraneura nigriabdominalis (Sasaki)

A second experiment was conducted in Urbana during the summer of 1975. Half of eight 50 x 50 ft. plots were inoculated in seedling stage with SMV; the other four were used as checks. The plants were sampled every two weeks to monitor SMV spread from inoculated centers. Two cylindrical sticky traps, one stationary, the other wind oriented, monitored aphid movement and timing throughout the growing season. They were serviced twice weekly and the samples are currently being separated and aphids identified from them. Results indicated that SMV did not spread more than 2% until early August, at which time and within a single week spread soared to 80% of the plants in all plots, including check plots. Infestation was lowest on the windward portions of the overall field which indicates that inoculum pressure came from within the field. These data are currently being analyzed. Although all of the aphid data has not been analyzed, that which has suggests that during the

time of the explosive spread of SMV, there was a correspondingly high proportion of alate aphids, some of which were the corn leaf aphid, Rhopalosiphum maidis. Tests are now underway to determine if this aphid is capable of transmitting SMV. So far results are negative; no transmission of SMV has been successful using R. maidis as vectors. An extensive series of experiments on SMV epidemiology is planned for the summer of 1976.

In a study of soybean colonization, Mark Mayse, a graduate student of Dr. P. W. Price, collected several species of aphids in soybean fields in Urbana (determined through IRCSA by Dr. M. Stoetzel, USDA Systematic Entomology laboratory):

Aphids craccivora (Koch)
Aphis gossypii Glover
Marcrosiphum euphorbiae (Thos.)
Macrosiphum sp
Myzocallis asclepiadis (Monell)
Rhopalosiphum maidis (Fitch)
Rhopalosiphum rufiabdominalis (Sasaki)

More than half of these aphids were collected near the edge of the field and only one out of twenty were captured near the center of the soybean field, even though equal collecting time was given to each locality.

2. Tobacco Ringspot Virus (TRSV). The vectors of this potentially important virus are not really known. Several arthropods (and a nematode) have been implicated. The major vectors probably belong to the Order Thysanoptera, the thrips. One of the most abundant insects in soybean fields in Illinois and throughout parts of Latin America is the soybean thrips, Sericothrips variabilis (Beach). Whether this insect is a potential vector of TRSV is of utmost importance to growers in the U.S. and Latin America.

Methodologies for thrips rearing were developed and studies of transmissibility of TRSV by Sericothrips variabilis were conducted under controlled conditions in growth chambers. All attempts to transmit the virus have proven negative. Although not as yet tested by us, Thrips tabaci and Frankliniella tritici have been found to transmit TRSV; the efficiency of transmission is far higher with T. tabaci. All three species of thrips occur in the soybean growing areas of the U.S., into Mexico and southward. Methodologies for studying virus-vector properties of these thrips will allow for more efficient study of related thrips in other areas.

f. Bionomics of Soybean Insects (cooperation with Drs. M. Kogan and G. Waldbauer).

1. Bean Leaf Beetles, Cerotoma spp. These insects are pests or potential pests of soybeans throughout the Americas. Adults feed on foliage, larvae attack root nodules containing nitrogen fixing bacteria, and adults are capable of transmitting bean pod mottle virus in soybeans.

A refined sampling technique showed that eggs of Cerotoma trifurcata (Forster) did not occur more than 3.8 cm below the soil surface. Series of contiguous cubical samples, running perpendicularly across a row and

halfway to the adjacent row in either direction, showed that over 73% of the eggs were within 2.5 cm of a row of plants and over 92% within 7.6 cm. These findings provide the basis for developing a sampling technique for determining absolute numbers of eggs per area of crop field.

There are three peaks of adult abundance in central Illinois soybean fields and up to five in more tropical areas. The colonists arrive shortly after soybean emergence in late May or early June and die after depositing eggs in the soil near the plants. First generation adults, present from mid or late July until the 2nd or 3rd week of August, also oviposit and then die. Second generation adults are abundant in September and leave the fields when the plants are senescent. They eventually move to overwintering sites and do not oviposit until the following spring. Peak egg abundance always occurred later than peak adult abundance.

Before soybeans emerged, adults were active in field but, no eggs could be found. Alfalfa may be an important interim food for adults in spring. Eggs were found in the soil near three native wild Leguminosae, Desmodium illinoense Gray, D. cuspidatum (Muhl.), and Strophostyles helvola (L.).

Changes in the phenological relationship between the soybean and the bean leaf beetles affect the duration of the plants' exposure to beetle injury, and may also have a significant effect on beetle population size. In Illinois, soybeans usually mature early enough to escape most defoliation by 2nd generation adults. Late planted fields escape the colonists. General late planting over a large area can result in a great decrease in bean leaf beetle populations since, in the absence of their most abundant food plant, most adults apparently die without ovipositing or at least without ovipositing on a suitable host for larval development.

The effect of larval bean leaf beetle feeding on soybean roots and nodules was studied in our laboratory with the participation of Miss Cathy Eastman, Department of Entomology, Louisiana State University. Model Systems were developed whereby the upper rhizosphere, containing the majority of the N-fixing bacterial nodules was confined in a small plastic enclosure containing a mixture of vermiculite and sand. The distal end of the root system passed through a hole in the bottom of the container and was immersed in a nutrient solution. Larvae introduced into the enclosure developed on roots and nodules 55 percent of which showed injury by the larvae.

2. The soybean thrips, Sericothrips variabilis. Soybean thrips populations were monitored in four areas of Illinois. Also, a systemic insecticide experiment was monitored at Dixon Springs.

Data from these experiments indicate that:

a. thrips abundance was greater in the southern than in the northern latitudes;

b. peak abundance of thrips populations occurred earlier in the south and later in the north;

c. thrips populations were greatly reduced early in the growing season with an application of carbaryl (Sevin);

d. the distribution of thrips on a soybean plant varied with stage, first instars were most abundant in the middle leaves, second

instars were most abundant in the middle and lower leaves, and adults were found throughout the plant but seemed to prefer the growing tips;

e. there seemed to be a slight preference for variety 'Williams' over variety 'Amsoy' at Dixon Springs;

f. adult thrips are extremely mobile and are capable of colonizing soybeans even when a systemic insecticide had been applied;

g. first instar abundance was the best index of thrips population level for the plots monitored;

h. the systemic plots were effective early in the season against a buildup of first instars (especially Disyston and Counter);

i. a thrips predator, Orius insidiosus, built up on thrips larvae and actually appeared to bring the thrips population to a very low level;

j. the yield difference between the check plots (no systemic insecticides) and the systemic insecticide plots were not significant;

k. the ability of Sericothrips variabilis to transmit tobacco ring spot virus (TRSV) has not been adequately demonstrated one way or the other, but data from current laboratory experiments suggest that the thrips are unable to transmit TRSV.

3. Orius insidiosus, a predator of Sericothrips variabilis. Orius is a major factor in the control of thrips populations. It is also a good predator on eggs of various lepidopterous pests of soybean. Different species of Orius occur in most soybean fields around the world. The population dynamics of all species are similar and their abilities to respond to outbreaks of thrips are great.

The outbreak of Sericothrips variabilis in southern Illinois in the spring of 1975 provided an opportunity to study the predation potential of Orius. Sampling procedures did not accurately monitor Orius abundance since most activity of this predator is during the night. However, enough of a correlation between thrips abundance and Orius abundance was obtained to suggest that Orius was a major factor in the control of the thrips. This important predator will be studied in detail in the next few years.

4. Lepidopterous caterpillar parasitoids. A survey of parasitoids of lepidopterous caterpillars was conducted over a two year period. Nine host species were sampled in Central Illinois from which were reared 23 species of dipterous and hymenopterous parasitoids and two hymenopterous hyperparasitoids. Apanteles marginiventris and Rogas nolophanae were the most abundant parasitoids of the green cloverworm.

5. Colonization of soybean fields by insects (cooperation, under direction of Dr. P. W. Price). Direct observation of 20 plants each on four zones in the field (border, two intermediate, and center) provided data on the dates of arrival and disappearance of soybean feeding insects and their natural enemies. The accumulation of species increased with the season with natural enemies usually lagging behind the appearance of their hosts or prey.

The maximum number of herbivor species observed in any one field did not exceed 25. The colonization curve reached a peak and dropped following senescence of plants. Data are being interpreted under the light of the island colonization theory.

g. Modeling (cooperation with W. G. Ruesink and M. Kogan). A static model was proposed by W. G. Ruesink for economic injury levels of soybean defoliators. Some characteristics of the model were investigated and it became apparent that although it served as a first approximation, additional refinement was needed to reflect the dynamic nature of economic injury levels of defoliators. Dynamic models for populations of the bean leaf beetl , the green cloverworm and the alfalfa caterpillar were prepared based on existing data. The models revealed considerable gaps in our basic biological information and stimulated the reassessment of o · research directions regarding those species.

Data needed to improve the models and validate their results are being gathered. These data include: (a) growth analyses of soybean plants and rates of recovery from various defoliation levels; (b) measurement of feeding rates of main soybean pests and influence of leaf age and population levels on feeding rates; and (c) behavior of the insect-feeding/plant-response system under field conditions.

A computer-based education program (on the University of Illinois PLATO system) was produced using data from the Illinois soybean pest management system. Besides its value as a tool in teaching pest management it was envisioned as a prototype of future on-the-farm decision making aid and a convenient method to model economic injury levels.

APPENDIX III-A

SOYBEAN PATHOLOGY

Fungal and Bacterial Diseases of Soybeans

Accomplishments

1. Identify the various seed-borne microorganisms and pathogens associated with soybean seeds from selected countries.

ETHIOPIA: Soybean seeds of 16 cultivars were harvested in 1973 and 1974 from field plots at three agricultural experiment stations in Ethiopia: Awassa, Bako and Debre-Zeit. This is the first report on a bioassay of soybean seeds grown in Ethiopia. The bioassay showed that 38 genera of fungi and the bacterium, *Bacillus subtilis*, were associated with the various seed lots. All but two genera of the fungi were new records for Ethiopia and 20 genera were new records for the world. As the percentage seed-borne microorganisms increased the *in vitro* germination decreased.

PUERTO RICO: A cooperative study between the soybean breeding-plant pathology program at the University of Puerto Rico is directed at finding those germplasm entries that show genetic resistance to internally seed-borne microorganisms. Studies are being conducted on the world germplasm collection of maturity groups VIII, IX, and X which have been grown at the Agricultural Experiment Substation at Isabela during 1975. The plant pathology laboratory has been given a 100-seed sample of each of the 397 germplasm entries of the collection. These samples have been bioassayed. At this report over 250 of the entries have been bioassayed with over 32 different genera of fungi identified. Some of the common genera of fungi found associated with the seeds are: *Alternaria*, *Aspirgillus*, *Botrydiplodia*, *Cercospora*, *Chaetophoma*, *Cladosporium*, *Corynespora*, *Curvularia*, *Diaporthe phaseolorum* var. *sojae* (*Phomopsis* sp.), *Fusarium*, *Penicillium*, and *Phoma*. Two common bacteria found were species of *Bacillus* and *Xanthomonas*.

Studies were completed earlier on microorganisms associated with soybean seeds grown in India. We have found B. subtilis associated with soybean seeds grown in Mainland China, Korea, Pakistan, and Thailand in addition to Ethiopia, Puerto Rico and the United States.

2. Determine the pathogenicity of the various isolated organisms and their role in reducing germination and emergence of soybean seedlings.

Soybean seedlots from six states and from many locations within Illinois have been bioassayed over the past several years. Tens of thousands of soybean seeds have been studied. One of the most important internally seed-borne fungi found associated with soybean seeds in the U.S., Puerto Rico and other countries is *Diaporthe phaseolorum* var. *sojae* (*Phomopsis* sp.) causal fungus of pod and stem blight disease. Seeds infected with this fungus rarely germinate, although they may be viable prior to germination. It is

one of the more important fungi contributing to the lowering of soybean seed quality. Infected seeds may show no symptoms or may be dull, shriveled, and lightweight. Seed infection increases when harvest is delayed due to wet, warm weather. There is high inverse correlation between the occurrence of D. phaseolorum var. sojae (Phomopsis sp.) in seeds and germination.

Seedlots of 12 soybean cultivars were harvested from either northern, central or southern growing regions of Illinois in 1973, 1974 and 1975. There were 39 lots of the cultivars Amsoy, Bonus, or Wayne harvested in 1973; 64 lots of Amsoy, Beeson, Clark, Corsoy, Cutler, Kent, Wayne, Wells, or Williams harvested in 1974; and 48 lots of Amsoy, Beeson, Hark, Wayne, Wells, Williams or Woodworth harvested in 1975. All seedlots were bioassayed for occurrence of seed-borne microorganisms and percentage in vitro germination was recorded. There were significant differences in in vitro germination between but not within years. There were significant differences in occurrence of seed-borne microorganisms between and within regions and years. Significant differences in the occurrence of D. phaseolorum var. sojae (Phomopsis sp.) was related to year and growing region but not cultivar. There was cultivar interactions in in vitro germination, occurrence of total fungi and Bacillus subtilis regardless of growing region and year. The use of in vitro germination alone is not sufficient for determining seed health, the occurrence of seed-borne microorganisms must also be made.

Cultivars differ in their susceptibility to seed infection by D. phaseolorum var. sojae (Phomopsis sp.). This difference may be due to differences in maturity groups, in susceptibility to seed infection by fungi, in amount of seed-borne inoculum and/or the number of seeds infected with fungi at the time of planting, or in the number of weeks of delayed harvest.

3. Study the sites of primary infection by various pathogens in the soybean seed.

Most of the pathogens of soybean are seed-borne. Soybean seeds before harvest become invaded by various microorganisms that can reduce seed quality and viability. Some microorganisms cause serious losses during the growing season. Seed infection also acts as a means of survival for many organisms. Some pathogens may remain viable longer than the seeds during storage. Seed infection may result in long range dissemination of the pathogen resulting in introduction of primary inoculum into areas where the pathogen was previously absent. Seeds may become infected at any time during their development, depending upon the pathogen involved.

Colletotrichum dematium var. truncatum (causal fungus of anthracnose disease), Diaporthe phaseolorum var. sojae (Phomopsis sp.) (causal fungus of pod and stem blight disease), and Cercospora kikuchii (causal fungus for purple seed stain) were isolated from and observed within the seedcoats of surface-sterilized soybean seeds. The mycelium of C. dematium var. trucantum was confined to the middle cell layer of the seedcoat, called the "hourglass" cell layer. The seedcoat symptoms of soybean seed infected with the fungus was similar to those described for Macrophomina phaseolina (Rhizoctonia bataticola). The mycelium of D. phaseolorum var. sojae (Phomopsis sp.) was abundant in the hourglass cell layer, less so in the parenchyma cell layer, and least in the palisade cell layer of the seedcoat. The mycelium of C. kikuchii was equally abundant in the hourglass and parenchyma cell layer with

a high concentration in the hilum region of the hourglass cell layer, but sparse in the palisade cell layer. B. subtilis was found in the hourglass and parenchyma cell layers of soybean seedcoats from surface-sterilized seeds of four cultivars. Reports in the literature show that the downy mildew fungus colonized the soybean seedcoat. These observations show conclusively that the primary colonization site of many seed-borne fungi and bacteria in soybean is in the seedcoat rather than on the surface or between the seedcoat and the cotyledons. This information has many implications for controlling seed-borne diseases of soybean.

4. Preparation of: "An Annotated Bibliography of Soybean Diseases, 1882-1974" and a "Compendium of Soybean Diseases".

The "annotated bibliography" was prepared under the coauthorship of J. B. Sinclair and O. D. Dhingra. It was published as INTSOY Series No. 7 and contains 280 pages. The publication of this bibliography marks for the first time that the world literature on soybean diseases has been brought together and annotated in a single volume. The detailed index will assist research workers and educators interested in diseases affecting soybeans in locating pertinent publications. The bibliography includes more than 2,250 citations and was supported in part by the Illinois Agricultural Experiment Station, USAID and INTSOY.

A companion book, "Compendium of Soybean Diseases" was prepared under the coeditorship J. B. Sinclair and M. C. Shurtleff. It was published by the American Phytopathological Society and contains 69 pages. The publication of this compendium marks for the first time the consideration of the world diseases of soybeans, including nonparasitic diseases such as herbicide injury, air pollutants, temperature extremes, and mineral deficiencies and toxicities. It was cosponsored by the American Phytopathological Society, the American Soybean Association, INTSOY, the Cooperative Extension Service and the Department of Plant Pathology (UIUC) and the Extension Service, USDA.

5. Cooperating with the soybean rust pathologists in exploring with AVRDC and other research organizations possibilities for cooperative research on soybean rust.

The Chiang Mai Conference provided a unique opportunity for the development of the International Working Group on Soybean Rust. The time was auspicious for a working group of scientists interested in soybean rust to form a more organized means of communication and cooperation.

Drs. Ford and Sinclair acted as catalysts by encouraging immediate implementation of suggestions by the soybean rust group. They provided motions from the floor concerned with the forming of the committee and officer selection, plus the development of a newsletter. It is anticipated that these men will continue to have an active role in the work of the soybean rust group. Drs. Bromfield, Ford, Sinclair and Yang will meet again concerning the activities of the rust group at the annual meetings of the American Phytopathological Society to be held in Kansas City in July 1976.

Elected officers of the International Working Group on Soybean Rust are:

Dr. Charles Y. Yang (AVRDC), Chairman
Dr. K. R. Bromfield (USDA, ARS), Vice-chairman
Mr. S. Shanmugasundaram (AVRDC), Secretary.

The purpose of the soybean rust workers group is to stimulate development of scientific information on soybean rust and provide a means for the rapid dissemination of data and materials among those scientists, worldwide, whose assignments and interests encompass any aspect of the soybean rust problem. Initially, dissemination of relevant information will be made through publication of a newsletter. The first newsletter will discuss the standardized rust assessment scheme developed at this session, and provide guidance for its use. It will suggest soybean materials for testing to be provided to members for rust reaction observations.

6. Control of Seed-borne Microorganisms of Soybean.

Seed treatment can reduce the deleterious effects of seed-borne fungi on soybean seeds and increase the emergence of low-quality seeds (germination below 70% and a high incidence of seed-borne fungi), but may have little or no effect on high quality seeds. A 3-year field and greenhouse study consistently shows that certain fungicides should be used on only poor quality seeds. Sinclair (see attached list of publications) reviewed the use of systemic fungicides as seed treatments for soybeans. Other work from this laboratory has shown that thiophanate-methyl, BD-18654, and methyl 2-benzimidazolecarbamate were absorbed by germination soybean seeds within 4 hours. Also, that the protectant, seed-treatment fungicides, Captan, and Thiram moved into the seed coats of treated soybean seeds, but not into the embryo tissues; while Benomyl, a systemic fungicide, was taken up by seedcoats and embryo tissues.

It has been reported that anhydrous dichloromethane (DCM) could be used as a carrier to introduce chemicals into seeds in the absence of water without apparent effects on germination and respiration. We have found that antibiotic activity can be dectected in the seedcoat and cotyldons of soybean seeds soaked in a mixture of potassium penicillin G and DCM; also, that the mixture had no effect on germination. We reported that DCM facilitated the movement of methyl 2-benzimidazolecarbamate (MBC) and thiabendazole, another systemic fungicide, into dormant seeds in the absence of water but not Captan, Thiram or carboxin, nonsystemic fungicides. Soybean seeds treated with MBC plus DCM and thiabendazole plus DCM has less occurrence of internally-borne total fungi, D. phaseolorum var. sojae (Phomopsis sp.), higher germination in vitro and emergence in vermiculite and soil than nontreated seeds or seeds treated DCM alone.

The solvents used in these studies are all volatile. The solvents carry the antimicrobial material into the seed coat (site of colonization by the internally-borne microorganisms) and evaporate when allowed to air dry, thus, leaving the fungicide or antibiotic in the seedcoat. No water is used, thus the seedcoat does not imbibe the solvent, but remains unswollen and firm.

The occurrence of D. phaseolorum var. sojae (Phomopsis sp.) and other seed-borne fungi in soybean seeds can be reduced with foliar applications of benomyl and other fungicides. We found that the amount of seed-borne fungi was significantly reduced below that of nonsprayed plants when soybeans were sprayed with one of the following fungicides or fungicide combinations: benomyl, benomyl plus captofol, chlorothalonil, mancozeb, thiabendzaole and thiophanate-methyl. Benomyl has been cleared by the EPA for use on soybeans and will be extensively used in the soybean growing areas of the U.S. in 1976.

APPENDIX III-B

SOYBEAN PATHOLOGY

Virus Diseases of Soybeans

Accomplishments

In the previous contract reporting period, a new virus disease of soybeans was discovered in experimental fields in Puerto Rico. Further studies that extended throughout the present contract year show that the disease is caused by a strain of cowpea mosaic virus (CPMV) a beetle transmitted virus that is also seed transmitted in cowpeas. Serological studies were conducted to establish the relationship between the Puerto Rico isolate from naturally infected soybeans and other strains and isolates of this virus. The disease caused by CPMV in soybeans was carefully described, and preliminary greenhouse studies on disease severity and sources of resistance were carried out. All varieties of soybeans so far tested are susceptible, and show very severe symptoms. Only rarely do infected plants produce seeds. Thus there is potential for serious damage by this disease in areas where the virus is present in cowpeas and where the beetle vectors feed on cowpeas and soybeans. Field studies to estimate yield losses and rates of spread, as well as more thorough testing for sources of resistance to the disease are planned for 1976-1977.

Cooperative studies with Dr. Julio Bird, University of Puerto Rico, Rio Piedras, were undertaken on the etiology of bean golden yellow mosaic and soybean yellow (or Rhynchosia) mosaic. The pathogens causing these diseases are whitefly transmitted. They had not before been characterized and were only presumed to be viruses. In the current contract year, we have shown that the causal agent of bean golden yellow mosaic is an unusual virus, perhaps belonging to a newly emerging but poorly understood class of virus pathogens from the tropics. Initial studies were conducted with the bean golden yellow mosaic disease because it was found possible to mechanically transmit the causal pathogen with high efficiency. Results of studies on the bean disease will, we hope, enable us to study the whitefly-transmitted viruses of soybeans that are so serious in tropical America and Asia.

An unusual virus or virus complex isolated from soybeans in Spain was studied. Originally thought to be caused by a new virus, the disease is now thought to be caused by an unusual strain of soybean mosaic virus. Further work is required to establish for certain whether or not a second virus is involved in this soybean disease.

Soybean mosaic virus (SMV) is both seed transmitted and aphid transmitted. Because it has a rather narrow host range among legumes, SMV is thought to be spread by aphids in the field from infected seedlings arising from infected soybean seeds, rather than from some outside alternative host plant. Thus, control of SMV spread could be effected by preventing seed transmission of the virus. In the present contract year, studies were begun on the mechanism and genetics of seed transmission of SMV in soybeans. Nearly 1000 soybean lines will be screened for seed transmission in 1976-77.

Results of preliminary studies in the greenhouse on SMV infection of flowers and immature pods show that methods currently available permit detection of the virus in single flowers or pods.

Cooperative studies were conducted with Dr. M. E. Irwin, INTSOY entomologist, on the field spread of SMV at Urbana and at Isabela, Puerto Rico. Little spread was detected in the winter season (Jan-Apr) in Puerto Rico. Extensive spread occurred in early August in the experiment at Urbana. A virus-free seed lot was used in each experiment, and approximately 0.5% of the plants were inoculated in the seedling stage. At Urbana, approximately 80% of the samples taken from the field on 11th August were positive when indexed for the presence of SMV, whereas of the samples taken on 25th July only 1% were positive. The rapid spread of the virus corresponded to a time when preliminary evidence shows large numbers of winged aphids (species not yet determined) were present in the field. Further detailed work on the mechanism of virus transmission by aphids and the conditions conducive to and patterns of field spread are now underway.

The USDA southern germplasm collection, maturity groups VIII, IX, and X, were evaluated twice during the contract year for the prevalence of seedborne SMV. Over 20 of the lines had a high proportion of seedborne virus.

Discussion

The discovery of an unusual viruslike particle associated with the golden yellow mosaic disease may represent a significant step forward in understanding the whitefly-transmitted causal agents of the serious yellow mosaic diseases of soybeans that limit soybean production in parts of the Indian subcontinent and threaten it in tropical America. It is not yet possible to say if the soybean diseases are caused by the same type of pathogen as the bean disease. However, numerous lines of evidence make that a likely outcome. The basic significance of this virus and the few others structually like it (from cassava, maize and the fungus Neurospora) is still to be explored.

We believe that the potential impact of breeding for resistance to seed transmission on crops where virus inoculum comes from infected seed (such as with SMV in soybeans) represents an area of research that could have a major impact on soybean virus epidemiology in tropical areas of the world where experience shows SMV to be a serious problem (e.g., Ecuador, Indonesia). If applied to other crops, such as lettuce, beets, common beans and cowpeas, it could also have a significant impact.

The discovery of isolates of CPMV that cause a severe disease of soybeans represents the first time that CPMV has been taken seriously as a soybean pathogen. This virus could have a major effect on the success of soybeans in areas where cowpeas are a favored crop (tropical America, Africa). There are several different but related viruses in the CPMV group, and some do not apparently seriously affect soybeans. For example, our preliminary results show that CPMV isolates from Surinam and Africa cause mild or no disease in most soybean varieties, whereas the isolates of CPMV from the Caribbean cause severe disease in every soybean variety tested. Because these viruses are seedborne in cowpeas, it becomes important to exercise caution in international shipping of cowpea seeds that may carry strains of CPMV that can spread to nearby soybeans and cause serious diseases.

APPENDIX III-C

SOYBEAN PATHOLOGY

Research in Puerto Rico Excluding Cooperative Studies

Introduction

In most crop production programs, the area of pathology has played a major role. This area is of equal importance in soybean production for the tropics. The purpose of the soybean pathology efforts is to develop an overall program to handle the pathological problems associated with soybean in the tropics. At the present time four major areas of research are being conducted. They are:

	Area of Investigation	Overall Goal
1.	Disease Nurseries	Plant pathogen problem assessment.
2.	Fungicide Spray Program	To determine the types of pathogens that can be controlled with the use of chemical barriers.
3.	Soybean Seed quality trials	To test the seed quality of soybeans produced under tropical conditions as compared to certified soybean produced in the U.S. mainland.
4.	Tropical Soybean Pathology Culture Collection	Cultures for dispersion to world soybean researchers and for further laboratory and field studies.

Accomplishments

1. Soybean Disease Nurseries. Soybean Disease Nurseries were established at the Agricultural substations of Adjuntas, Isabela, Lajas and Fortuna. The four different regions provided variation both in environment and pathogen populations. Seven soybean varieties were planted in replicated trials at each location. The varieties selected for this study were:

1. Improved Pelican
2. Williams
3. Bonus
4. Clark 63
5. Hardee
6. Pickett 71
7. Biloxi

These varieties were chosen because of their differences in susceptability to known pathogens of soybeans. The purpose of establishing the identical experiment at 4 sites was to obtain an understanding of the types of plant pathological problems for a given area. The assessment of the major pathological problems is a must in order that time and money be best directed to study and solve the most critical problems.

Weekly visitations were made to each location to determine the general health of each variety at each location. Soybeans of each variety were harvested at both physiological maturity and at a 30-day delayed harvest. Seed samples were then studied in the laboratory for such seed quality characteristics as 500 seed weight, percent visual cercospora purple seed stain, and a 200 seed bioassay for internally seedborne microorganisms.

General Conclusions of the Disease Nursery Trials. a. Soybean varieties differed in amount of foliar pathogen attack from location to location. b. Seed quality of each variety differed from each location of production. This can be attributed in part to pathogen population levels and other environmental factors. c. In all cases delayed harvested seeds of each variety decreased in seed quality.

Note: Weather data and soil samples have been collected and data obtained will be used to better understand the interaction of environmental factors with pathogen populations of the area.

Summary. Additional disease nursery situations should be established to monitor plant pathogens for a given location with increased soybean production of that area. Being able to assess the major pathological problems will enhance the effectiveness of plant pathology research efforts.

2. Fungicide Spray Field Program. One area of plant protection that has been given considerable attention in a crop production program is the controlling of plant pathogenic organisms through the use of chemical barriers. This means of controlling pathological problems has proven to be most effective in those instances where genetic resistance has not been developed for a particular pathogen.

The purpose of the fungicide spray program was to ascertain the effectiveness of chemical control using a systemic (Benlate) and a nonsystemic (Dithane M-45) fungicide for the control of both foliar and seedborne microorganisms under tropical conditions. These chemicals were chosen since similar studies had been conducted at the University of Illinois for the past 3 years and therefore a good base of comparison.

The identical fungicide spray program was conducted at the Agricultural Experimental Substations of Isabela, Adjuntas and Fortuna. The purpose of three locations was to assess the effectiveness of these two fungicides under different environmental and pathogen level populations. The rates at which the chemicals were applied for both Dithane M-45 and Benlate was 1/4, 1/2, and 1 pound per acre. The application times were at mid pod and two weeks later, mid pod only, and two weeks after mid pod only.

Summary of Goals for the Fungicide Spray Field Trials. a. To determine if commercial rates of fungicides with minimal number of spray applications would control seedborne pathogens. b. To determine if a yield increase response occurred because of the fungicide applications. c. To determine if the major foliar fungal pathogens were controlled. d. To make laboratory determinations of seed quality attributes by measuring yield, 500 seed weight percent visual cercospora purple seed stain, and a bioassay for internally seedborne fungi and bacteria.

Preliminary Results

a. There were many instances at all locations of increased yield of plants sprayed with fungicides as compared to non sprayed checks.

b. There appear to be significant differences in 500 seed weights between sprayed and non sprayed plots.

c. There were significant reductions in the percentage of Cercospora purple seed stain in sprayed plots over non sprayed plots.

d. Visual observations revealed that sprayed plots looked "healthier" than non spray plots. (A disease severity index was not conducted).

e. There was variation in the effectiveness of each fungicide depending on location.

f. Laboratory bioassay of seeds for internally seedborne microorganisms have not yet been completed, therefore no generalization can be made at this time.

Summary

The area of plant protection through the use of chemical barriers is needed in the overall program in tropical soybean production. There is much need to continue research in this area to find the most effective chemicals and how their uses can be directed at the small farm level. This study has laid the foundation for the initiation of these types of investigations.

3. Soybean Seed Quality Trials. The purpose of this type of investigation is to assess the "seed health" of soybeans produced in Puerto Rico as compared to certified soybeans produced in the U.S. (mainland).

This trial involved the growing of seeds from the soybean varieties that had been produced in the Isabela Disease Nursery. The purpose was to compare the performance of the original certified seed to 1st and 2nd harvest seeds of the same variety under field conditions. In a second portion of the experiment we wanted to test the "seed health" of soybeans produced from the Fungicide spray field trial in comparison with the original certified seed and non sprayed checks.

Preliminary Results

a. Yields of original certified seed was equal or greater than that of seeds of 1st or 2nd harvest of each variety.

b. Plants grown from fungicide treated spray field seeds yielded 25-30% over plants grown from non sprayed checks or original certified seed.

c. In general the percentage of plants at germination and plants to maturity were greater for original seed and 1st harvest seed than for second harvest seed.

d. Data on soybean yield components have been taken but not summarized.

e. Laboratory bioassay for internally seedborne microorganisms have not yet been completed.

Summary

Continued research efforts in this area are needed to assess "seed health" under field conditions. Soybeans produced in the tropics should be tested for field germination, internally seedborne microorganisms, yield and other agronomic factors before dispersed for use at the small farm level.

4. Tropical Soybean Pathology Culture Collection. The purpose of developing a tropical soybean culture collection is to provide a means by which to maintain a semi-permanent record of fungal and bacterial organisms that have been found in association with soybeans under tropical conditions.

Laboratory cultures of fungi and bacteria are maintained on Potato Dextrose Agar culture tube slants. Cultures are covered with sterile mineral oil for preservation. Duplicates of each culture are made and ready for dispersion to other soybean researchers around the world and for further laboratory and field investigations.

The present culture collection consists of 25 different genera of fungi and 2 genera of bacteria. With continued research it is expected that the collection will grow substantially. The maintenance of an up to date culture collection is a must for an International program to be effective both at home base and abroad.

APPENDIX III-D

SOYBEAN PATHOLOGY

Cooperative Research in Puerto Rico with Soybean Breeding

Introduction

The past five years of research in seed pathology at the University of Illinois has clearly shown the importance of good seed quality. This research has been primarily centered around investigations of the relationships of internally seedborne microorganisms to soybean seeds of established varieties. The incidence of seedborne diseases has in the past been attributed to natural pathogen populations and environmental conditions which favor pathogen invasion of host tissue. Recent research efforts have tended to indicate that some varieties studied may show some form of genetic resistance to the invasion of seedborne microorganisms. This concept is only speculative at the moment.

The cooperative study between soybean breeding-plant pathology is directed at finding those germplasm entries that show genetic resistance to internally seedborne microorganisms. Studies are being conducted on the world germplasm collection of maturity groups VIII, IX, and X which have been grown at the Agricultural Substation of Isabela during 1975. The plant pathology laboratory has been given a 100 seed sample for each of the 397 germplasm entries of the collection. These samples undergo a bioassay to determine the percentage of internally seedborne microorganisms. This bioassay consists of planting 100 surfaced sterilized seeds of each entry on 25 petri dishes containing Potato Dextrose Agar (Difco) (4 seeds/plate) and incubating them at 25 C for 5-7 days. After the appropriate incubation period data is then recorded pertaining to percentage germination, fungi and bacteria.

The goals of this cooperative study may be summarized as:

1. To identify genotypes with resistance to seedborne microorganisms.

2. To study the relationship of seedborne microorganisms and tropical germplasm.

3. To develop techniques for assaying "seed quality attributes" of tropical germplasm and breeding lines.

4. To incorporate "seed quality attributes" into tropically adapted cultivars.

Accomplishments

At present over 150 germplasm entries have been bioassayed in the laboratory for internally seedborne microorganisms. There appears to be a high correlation between the visual seed quality score assigned to each entry and the laboratory results of percentages of germination, fungi and bacteria. Differences between germplasm entries appear to be genetically controlled to some extent since growing and environmental conditions were equal.

Some of the common fungi found in association with germplasm bioassayed to date are: Corynespora, Cladosporium, Alternaria, Fusarium, Botrydiplodia, Cercospora, Curvularia, Phoma, Chaetophoma, Aspirgillus, Penicillium, and 7 forms of sterile white mycelium fungi. Two common bacteria found are Bacillus and Xanthomonas.

Recently an experiment has been established at the Agricultural substation of Isabela by which we will test those germplasm entries that were most favorable in laboratory tests in terms of high germination and low percentages of internally seedborne fungi and bacteria. The major goals of this experiment may be defined as:

1. To test if our laboratory evaluations are reliable interpretations of the expected performance of these germplasm entries under field conditions.

2. To test if the apparent resistance from the preliminary field trials is maintained throughout this experiment and a second laboratory evaluation.

3. To identify genotypes that maintain "good seed quality attributes" when the harvest is delayed after physiological maturity.

4. To evaluate agronomic characteristics of selected germplasm entries.

Summary

The search for soybean material showing resistance to seedborne microorganisms is a goal of high priority. Future laboratory work will center around continued evaluation of germplasm entries not as yet tested. New field studies to test apparent resistance will be developed. Eventually, attempts will be made by the plant breeder to incorporate this quality of resistance to seedborne microorganisms into promising lines adapted for the tropics.

APPENDIX III-E

SOYBEAN PATHOLOGY

Cooperative Research in Puerto Rico with Agricultural Engineering

Introduction

The topic concerning the importance of seed storage in tropical areas has already been covered in considerable detail in this report. The purpose of the plant pathology cooperation in this study is to relate the association of internally seedborne microorganisms to their effect on seed storage. A considerable amount of work has been conducted at the University of Illinois in an attempt to show the importance of seedborne organisms in seed quality deterioration. The majority of the work has been with a bacterium Bacillus subtilis which has been shown to reduce soybean seed quality drastically under poor storage conditions. Little work has been done showing the relationship of internally seedborne fungi to seed deterioration in storage.

Accomplishments

Seed samples from the 3, 6, and 9 month harvest periods of the storage experiment were given to the plant pathologist for determination of internally seedborne microorganisms. A bioassay was conducted on each sample to obtain data concerning percent germination, fungi and bacteria. The goal of these tests was to attempt to correlate the deterioration of soybean seed quality in storage with an increase in seedborne organisms.

General Conclusions from Laboratory Analysis

1. In general more fungi were isolated from soybeans bioassayed from the 3-month storage period than the 6 or 9 month period.

2. After 6- and 9-month storage periods samples had drastic reductions in percent germination and higher percent of Bacillus subtilis associations with dead seeds. The percentage of fungi was reduced at these longer storage periods.

3. Soybean seeds stored in the sealed metal can and metal can with plastic lining expressed highest levels of good seed quality after 9 months storage. The seeds stored in the fertilizer bag and cloth bag showed extremely poor germination percentages and higher levels of microorganisms than the previous two containers.

The Phase II study of the storage experiment is presently being initiated. Soybeans of the variety "Woodworth" grown in Puerto Rico will be used. Once again sample of the stored seed will be given to the plant pathologist for internally seedborne microorganism determinations. This data plus that collected from the storage experiment using certified "Woodrorth" soybean seeds from the U.S. will help us determine the storage potentials of these two differently grown seed sources.

Summary

The importance of understanding the factors of soybean seed deterioration in situations of tropical seed storage is critical. Regardless of the initial seed quality of the soybeans or genetic background poor storage will destroy the usability of the seed at the small farm level. Developing effective storage techniques to control the deterioration of the soybean seed to internally seedborne microorganisms is a must if this crop is to flourish at small fall levels of soybean production.

APPENDIX III-F

SOYBEAN PATHOLOGY

Cooperative Research in Puerto Rico with Mycology

Discussion

The service goal of the mycology section is to provide fungal identifications and ecological data for storage, breeding, and plant pathological investigations. The research goal of the mycology section is to test the applicability of the concepts of general ecology to plant pathological problems.

A study is currently underway to analyze the community structure of soybean fungi along a temperature gradient. The three, immediately practical results of the experiments are: (1) determination of the best temperature for seed quality testing of seeds produced in the tropical environment of Puerto Rico (this information is needed in the breeding project), (2) to discover whether each seed harbors several internally borne fungi only one of which is activated under a particular set of conditions, and (3) to determine the optimum temperature for pathogenesis by each of the common seedborne fungi. The later two results are important to the development of seed storage practices in the tropics.

Of more general interest is the study of the ecological diversity of these fungal communities. This information will lay the theoretical ground work for possible biological control of plant pathogens. By analyzing the evenness of distribution of the individual among the species present, dominance patterns for each species can be determined. These patterns indicate how well a species can compete with other microorganisms across a range of conditions (in this case temperature). They will also show whether dominant fungal species tend to be generalist with the capacity to occur over a broad range of conditions as has been suggested by studies with higher plants. Preliminary results indicate that the expected decrease in species richness and ecological diversity and increase in dominance to indeed occur in fungal communities as harshness of the environment increases.

Additional temperature experiments with insolates of the dominant species from the different temperatures will reveal the degree of correspondence between fundamental and realized niche widths and will indicate whether the breadth of the fundamental niche is due to genetic heterogeneity or phenotypic plasticity. (The investigators are aware of the possible complications of heterocariosis.)

The final result of these experiments will tell us whether those fungi best able to compete with the plant pathogens are generalists or are specialized for the limiting factor in each particular set of conditions. We must know this in order to plan a strategy for the microbiological control of plant pathogenic fungi.

The studies described above are being conducted during the current semester with the cooperation of the graduate students of the advanced mycology course. The project has the additional benefit, therefore, of providing training in plant pathological and ecological research methods.

A project designed as a coordinated study of funal succession and germination loss in stored soybean seed is proposed for the 1976-1977 academic year (this research will be in cooperation with the agricultural engineering and seed pathology laboratories).

These experiments will determine the rate of loss of germination during storage and correlate germination loss with the occurrance of the specific fungi present at each test period. The distinctive aspect of this study is the inclusion of systemic fungicide and antibiotic treatments at each test period to descriminate between germination lost under storage conditions and germination lost to microbial activity at the time of seed germination. Taking as a model studies conducted on small grains it is hypothesized that germination loss soon after harvest is associated with "field" fungi activated at the time of the germination tests, while later germination loss is associated with a distinct community of "storage" fungi which remain active under storage conditions.

This study will provide the theoretical base for planning seed treatment and storage strategies to avoid postharvest seed deterioration. Graduate students in the Fungal Taxonomy course will be involved in the proposed study.

APPENDIX IV

SOYBEAN FOOD USE

Accomplishments

Research was conducted in the following areas:

1. Two food science graduate students worked under the supervision of staff members on the development of (a) concepts for rapid preparation of weaning foods, and soybean:cereal patties that could be fried and used as meat substitutes in the diet, and (b) a procedure for preparation of a highly palatable soy beverage for village industry or home use.

2. Work was initiated on a filtering device for use in preparation of a soy beverage at the village level. (see 1.)

3. An extensive search was concluded for a low cost mill suitable for coarse grinding of dry materials.

4. A study was made to test the possibility of preparing drum dried soy:cereal products by using flours made from whole corn, whole wheat and brown rice.

5. Twenty-four varieties of soybeans were tested using four cooking methods. Tenderness of the soybeans was compared to many chemical and physical factors in a search for characteristics which correlated to tenderness of the cooked soybeans.

6. A study was made on the effect of using different fractions of corn and preparation techniques on the nutritional quality of drum-dried soy:corn flakes. Results of this study are not yet available.

Summary

A summary of the principle findings follows:

1. Concepts for Village Level Preparation of Soybean Based Food Products.

A method was developed for preparing: (a) weaning foods or fried soy:cereal patties from raw whole soybeans. The method involves grinding or breaking dry, raw soybeans before cooking. The product may be further ground after cooking. A suitable grinder is a hand powered disc grinder. Organoleptic tests indicated that soy-corn, soy-sweet potato and soy-wheat combinations were highly acceptable. (b) a method for preparation of a highly acceptable soy beverage for village or home industry is under development. The concept involves very low level technology. Necessary equipment includes a hand grinder, Waring blender or equivalent, cooking pots, and a filtering device (see next section). The basic procedure includes dry grinding, enzyme inactivation by dropping the broken beans into boiling water, blending to a slurry, heating and filtering. Presently a beverage containing 2.5% protein can be prepared. Research is being continued in an effort to raise this to 3%.

2. Filter for Village Level Soy Beverage Production.

Three filtering devices were manufactured and tested--a basket centrifuge, a swinging cradle, and a sock filter. Preliminary results indicate that the sock filter is as effective as the other two and it is clearly the cheapest and easiest to use. It also resulted in considerably less sediment in the final product. Further tests are being conducted with the sock filter.

3. Low Cost Dry Grinding Mill.

A small 2 H.P. hammermill, for coarse grinding cereals and soybeans, was purchased from Decker Manufacturing Co., Rockford, Illinois for about $700. The unit, which is constructed of mild and hardened steel, will be evaluated during the next six months.

4. Preparation of Drum-Dried Soy:Cereal Flakes.

a. Up to 20% whole soybeans could be mixed with whole corn or brown rice without significant loss in the characteristic cereal flavor and texture of the drum dried product. Organoleptic scores for drum dried soy:whole wheat (4:1) were lower than for drum dried 100% whole wheat.

b. Gelatinization of the soy:cereal mixtures before drum drying improved the organoleptic quality of soy:whole corn flakes. For the other soy:cereal flakes tested in these experiments, gelatinization was detectable by taste panelists but the average organoleptic ratings were similar for both gelatinized and ungelatinized products.

c. Bicarbonate solutions were added to soy:cereal mixtures in an attempt to reduce hang-up. When 0.05% sodium bicarbonate or 0.1% ammonium bicarbonate solution was added to the soy:cereal slurry before drum drying, off-flavor and hang-up were reduced, but not eliminated.

d. In one experiment the soybean slurry was prepared by adding raw full-fat soy flour to boiling water. Results are very preliminary but they indicate that this may be an alternative method to cooking the whole soybean and then grinding with a Waring blender or hammermill.

5. Effect of Variety on Tenderness of Cooked Soybeans.

a. The most important factor affecting tenderness of cooked soybeans was soaking and cooking solution. Use of bicarbonate solution instead of tap water increased tenderness of the soaked and cooked soybeans about 3 fold.

b. Soaking before cooking increased tenderness about 1.5 fold. The effect of soaking varied with the use of bicarbonate.

c. Tenderness of cooked soybeans varied about 2-fold with variety. The relative tenderness varied with the soaking/cooking solution used. No variety was consistently softer than the others for the four cooking methods tested.

d. For the varieties tested from the 1974 crop, the following factors correlated with tenderness of the cooked soybeans: initial moisture content, weight per bean, volume per bean, cooked weight per bean and cooked volume per bean.

6. Effect of Corn Fraction and Processing Method on PER's of Drum Dried Soy:Corn Flakes.

Soy:corn flakes were prepared by drum drying. An experiment was designed to test the effect of: (a) ratio of soy:corn, (b) fraction of corn used to prepare the flakes, and (c) gelatinization before drum drying. At this time complete nutritional and analytical data has not been received from the analyst.

Discussion

1. Concepts for Village Level Processing or Preparation of Soybean Based Food Products.

An area of vital interest is village industry processing and home use concepts for soybeans. A serious problem or deterrent to home or village industry utilization of soybeans is the long cooking time to achieve acceptable tenderness. Whole soybeans, prepared by accepted cooking methods, require soaking periods of 6-8 hours at about room temperature followed by a cooking time of at least two hours. The long cooking times, that are required to achieve satisfactory tenderness, are wasteful of fuel and seriously discourage village industry and home use of soybeans. Thus, there is considerable interest in developing concepts for rapid preparation of certain soy based products for village level use. Concepts for two types of products are under development. The first concept concerns products such as weaning or breakfast foods and soybean-cereal patties that can be fried and used as a substitute for meat in the diet. The weaning foods can be prepared starting with the raw, dry bean in about 30-40 minutes total cooking time plus a few minutes for grinding and maceration. The fried soy-cereal patty requires a slightly longer preparation & cooking time due to the frying operation. This concept was investigated by a graduate student working on a Master's degree. The study was supported by the Food Science department. This work is completed and will be submitted for publication this summer. According to this concept, the raw, dry beans are broken and/or ground before or after cooking or at both times. The most ideal grinder for this purpose is a type which forces the product between two flat grinding plates that are under tension to give the desired fineness of grind. This type of grinder is manufactured in a number of countries and we have purchased units made in South America and in Poland. Nutritional studies have not been carried out on these products.

However, theoretical calculations indicate that certain cereal-soy combinations should result in very good protein quality. Weaning and breakfast food products were prepared and organoleptically tested using combinations

of soy-banana, soy-corn, soy-sweet potato and soy-whole wheat. Fried patties were prepared from soy-rice and soy-white potato with a garnish of onion and green pepper. The products were rated for appearance, texture and flavor by an organoleptic panel made up of graduate students and staff. All products were rated as highly acceptable with one exception. Texture and flavor of the soy-banana weaning food was rated as acceptable but appearance was well below the minimum acceptability rating. This was due to excessive browning or oxidation of the banana. However, it is believed that the darkening problem can be corrected with further studies. These products offer a novel concept for preparation of high protein foods that appears to have considerable utility for people interested in high protein vegetarian foods in developing as well as developed countries.

The second concept concerns the development of a procedure for preparation of a highly palatable soy beverage for village industry or home use. This work is also being carried out by a Master's candidate who is being supported by INTSOY. It is estimated that this graduate student research will be completed by late fall 1976. This concept uses a very low level of technology and requires a grinder which is capable of particle size reduction similar to that achieved in a Waring blender, cooking pots and pans and a filtering device. The filtering device which appears most desirable is a long tube or sock which is fabricated from polyester cloth. Description of this and other filtering devices are presented in another section of this report.

Broken or crushed raw dry beans, whole dry raw beans or ground dry raw soybean powder is dropped directly into boiling water and given a short cooking time to inactivate the off-flavor producing enzyme lipoxygenase. The blanched material including the blanch water is ground in a Waring blender and the resulting slurry of soy solids is simmered for about 30 minutes to eliminate trypsin inhibitor and other anti-growth factors. After cooking, the slurry is filtered and the particulate solids are removed. Effort is being directed towards developing a preparation procedure that will result in a finished beverage of three percent protein. Presently a beverage of about 2.5% protein can be consistently prepared using this technique.

Extensive taste panels have not been conducted. However, it does appear that a bland beverage, completely free from beany, painty taste can be prepared. In addition, the filtering procedure, using the sock or tube gives a filtered product of very acceptable texture or mouthfeel. No work has been carried out on flavor addition but previous work with soy beverages indicate that this product should be very compatible with all types of flavors.

In summary, the results obtained to date indicate that the concepts described above are sound. Prototype food products with highly acceptable flavor and texture were produced from whole, raw soybeans in less than 1 hour. Further research and development is needed to explore possible problem areas, processing methods and products.

2. Development of a Filtering Concept for Village Level Production of Soy Beverage.

Effort on this project was directed towards development of a preparation and processing concept for village level production of soy beverage

and in developing and testing methods that could be used for filtering the soy beverages. The first phase of the work, development of the preparation and processing concept, is being carried out by a graduate student as a research thesis topic for the Master of Science degree. Information regarding the overall concept for village level production of soy beverage is covered in another section of this report.

The second phase of this study was concerned with developing, constructing and testing three devices for filtering soy beverage slurry to remove particulate, ground soy solids. These methods were based on a low to intermediate technology. Preliminary tests were compared and evaluated to determine performance of the three filtering systems. The method of preparation of a slurry from whole soybeans, description of each of the filtering devices used in removal of unwanted solids, the data obtained and conclusions are presented below.

Preparation of Slurry. The term "slurry" is defined as follows: The slurry represents a water mixture consisting of ground whole soybeans of varying particle size.

The soybean slurry is prepared as outlined in Figure 1.

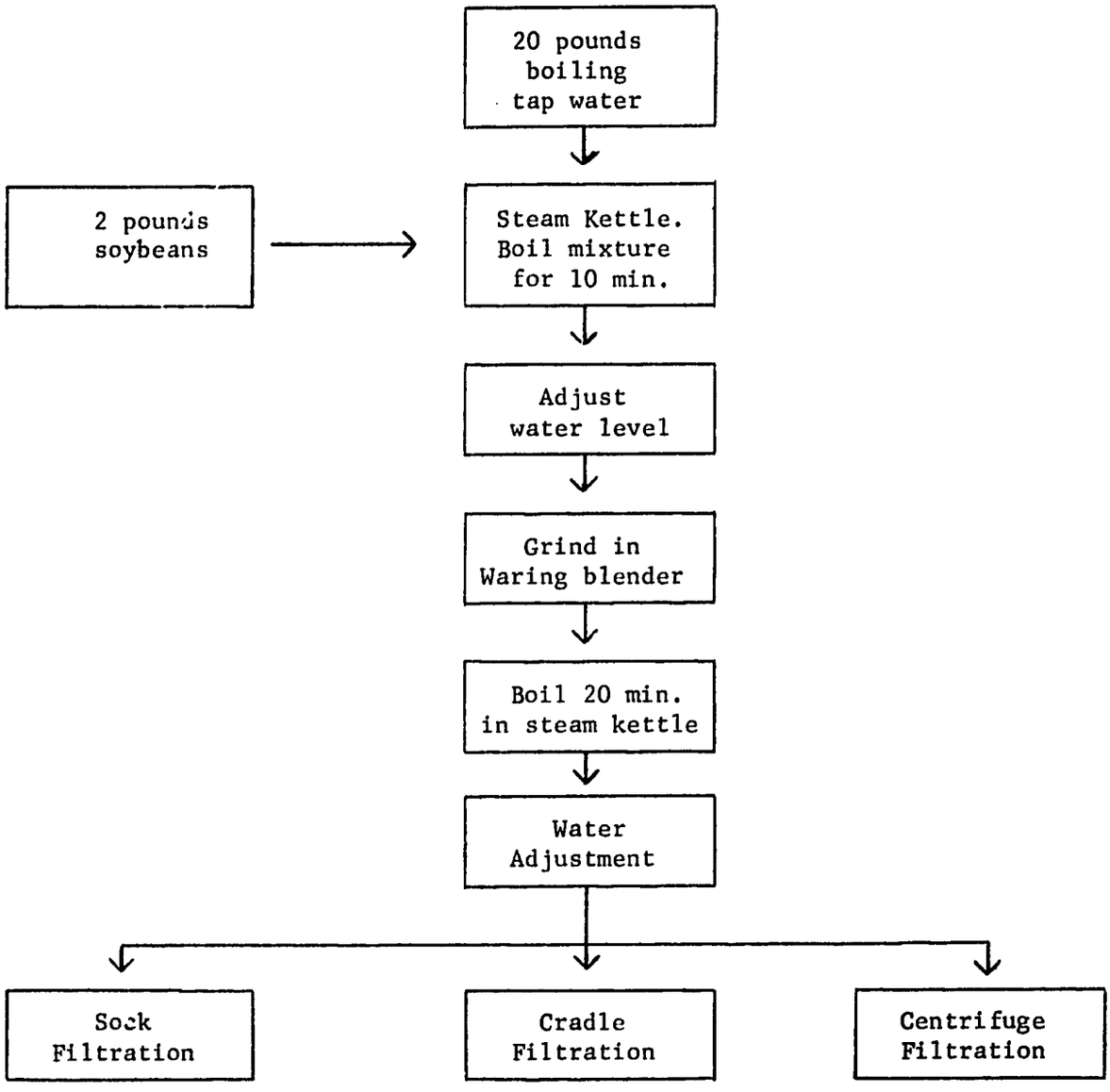
Two pounds of cleaned Bonus 1973 whole dry beans were added to 20 pounds of tap water in a steam jacketed kettle. This material was brought to a boil and simmered for 10 minutes, removed from the kettle and adjusted with tap water to a total of 22 pounds. The mixture of beans and blanch water was separated and each portion was used as follows: The drained beans were roughly divided into two batches and one batch was added to the large Waring blender with just enough drain water to cover the beans. This minimum amount of water facilitated the grinding of beans to a finer particle size. Each batch was blended on medium speed for one minute, followed by one minute on high speed. When both batches were ground with small amounts of added water, they were combined and again ground for one minute on high speed. Following this, the mixture was combined and returned to the steam kettle for an additional 20 minute simmering with constant agitation. After simmering, the slurry was again weighed and adjusted with water to a total of 22 pounds.

Samples were thoroughly stirred to insure uniform distribution of ground constituents before sampling for filtration.

Filtration of Slurry by Sock Method. The solid soybean particles were removed from the slurry by this method using a cloth sock having dimensions of 6" x 76". Two smooth pieces of 3/4" thick wood, about 1 1/2" x 12", are clamped using bolts and thumbscrews, to the bottom of the cloth sock, Figure 2.

The unfiltered slurry is poured into the sock from the open top end and allowed to drain into a tub until the pores of the sock become clogged. When this takes place, the operator rolls up the sock using the wooden clamp. This squeezes more fluid from the slurry. The sock is again unrolled and slightly shaken which unclogs the pores in the cloth. This procedure is repeated as many times as is necessary to squeeze the free liquid from the particulate soy solids.

FIGURE 1. SLURRY PREPARATION



The cloth found most satisfactory for this method of filtering consisted of 100% polyester and was sold under the trade name of "Butterfly." The physical characteristics of this cloth resembled heavy silk. This cloth contained 70 threads per inch, with each thread having a diameter of about .0025" and a spacing of about .012" between threads. A filter sock or bag made from this material can be easily cleaned by turning inside-out. Since this material does not absorb moisture, it is readily sanitized after and before each use.

Filtration of Slurry by Cradle Method. The illustrations, Figure 3, show the construction and indicate the general operation of this method. Essentially a half section of a metal cylinder, having a radius of 18", a depth of 18" and a width of 16" is pivoted on a shaft to enable its operator to rock the cylinder back and forth with regard to the pivot point. As shown in Figure 3, the bottom of the cylinder is fabricated from a perforated stainless steel plate which is covered with cloth similar to that used in the sock filter. As the cradle is rocked back and forth, a stationary paddle or squeegee moves the slurry across the filter cloth. The liquid product passes through the cloth and perforated steel plate and into the receptacle below. This operation is continued until essentially all liquid is removed from the ground soybean solids.

Filtration by the Centrifuge Method. This method of filtration utilizes a centrifuge basket which is lined with cloth similar to that used in the sock filter. The basket revolves at 900 rpm and is constructed of a solid stainless steel 15" base and the side is made of perforated (1/8") metal and is 6" high. In operation, the slurry is poured into the revolving basket and the liquid passes through the cloth and perforated side into a larger semi-covered chamber where it drains into a bucket. The cloth is removed for solids removal and cleaning. Figure 4. shows two views of the basket type centrifuge.

Conclusions

The three filtering devices were tested using standard slurries and operating procedure. The filtrate (beverage fraction) was analyzed for protein, solids and sediment. Protein was determined by multiplying Kjeldahl nitrogen by the factor 6.25. Solids were determined by the AOAC vacuum oven method. Sediment was determined by allowing 100 ml samples of filtrate to stand in 100 ml graduate cylinders for 24 hours at 34°F. After standing, the amount of sediment was readily evident in the cylinder and was reported as percent of sediment. The data is presented in Table 1. Examination of the data shows that the filtered products contained similar protein and solids content regardless of the filtering device used.

There was a difference in the total amount of product produced by each of the devices. The centrifuge was the most efficient in removing the liquid product from the unfiltered slurry, followed by the sock and then the cradle. This is shown in the % yield of product column of Table 1. However, the sock method is by far the simplest and least expensive of the three schemes developed for filtering the soy slurry. Use of the sock method also resulted in significantly less sediment. This is desirable and generally results in better mouth-feel of the soy beverage. Thus, this method is being adopted for use with the concept for production of soy beverage at the village level.

FIGURE 2. SOCK FILTER

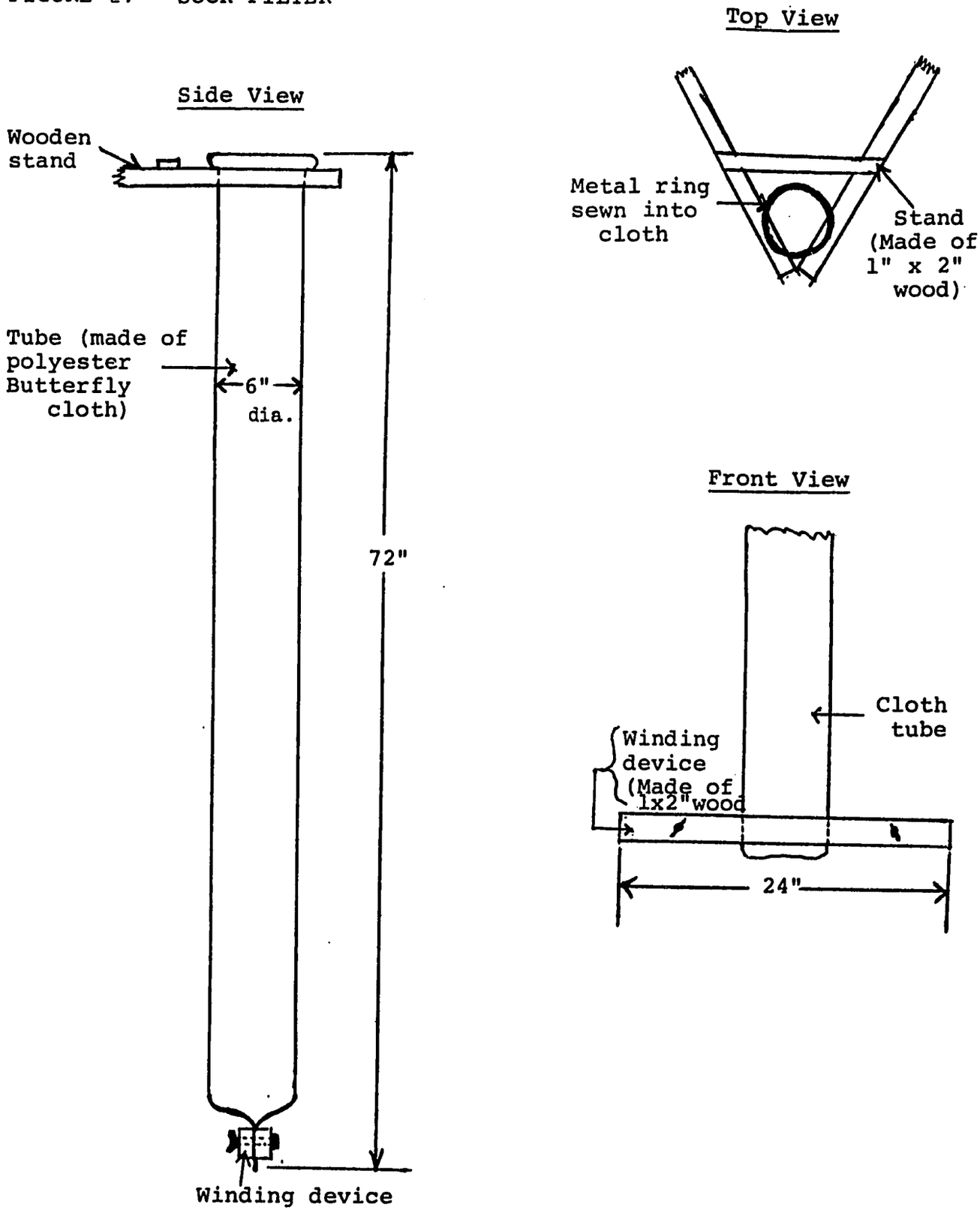


FIGURE 3. CRADLE FILTER

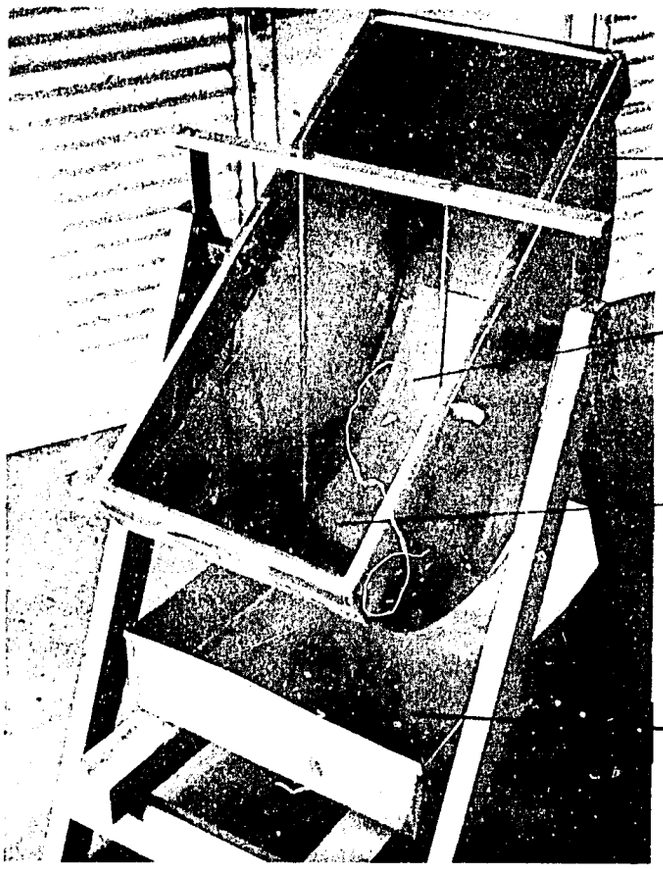
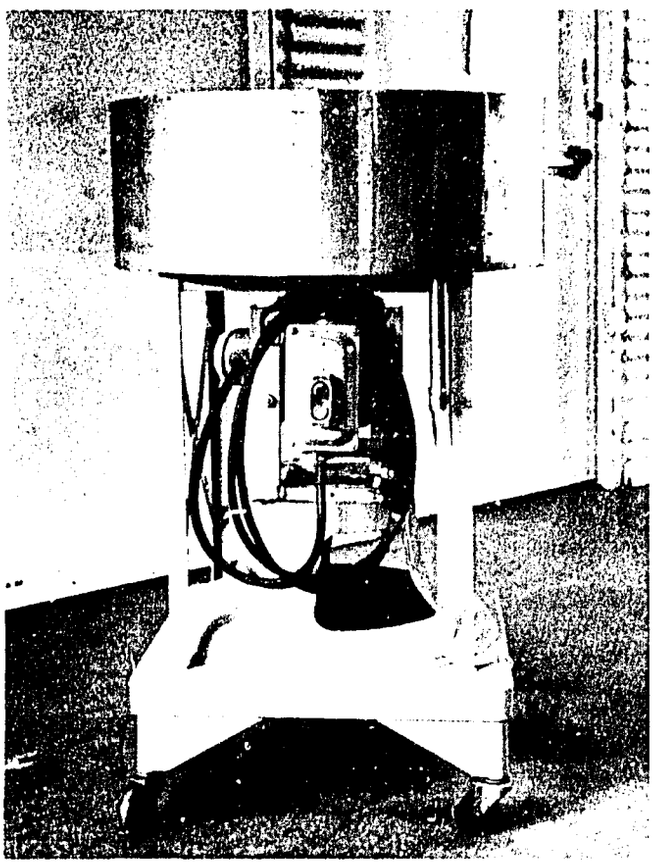


FIGURE 4. CENTRIFUGAL FILTER

TOP VIEW

ROTATING PERFORATED STEEL BASKET

COLLECTING DRUM



SIDE VIEW

TABLE 1. SOY BEVERAGE CHARACTERISTICS AFTER FILTRATION

	% Protein	% Solids	% Sediment	Wt. Product	Wt. Protein	% Yield Product
SOCK FILTRATION						
	2.8	5.7	10.0	16.8 lb.	.47 lb.	76.4
	2.4	4.7	15.0	16.3 lb.	.38 lb.	74.1
(Mean)	2.6	5.2	12.5	16.6 lb.	.43 lb.	75.3
CRADLE FILTRATION						
	2.2	4.9	23.0	14.8 lb.	.32 lb.	67.3
	2.3	5.1	25.0	14.6 lb.	.34 lb.	66.4
(Mean)	2.2	5.0	24.0	14.7 lb.	.34 lb.	66.9
CENTRIFUGE FILTRATION						
	2.4	5.0	21.0	17.4 lb.	.42 lb.	79.1
	2.3	4.8	20.0	17.2 lb.	.39 lb.	78.2
(Mean)	2.4	4.9	20.5	17.3 lb.	.41 lb.	78.7

In summary, it appears that the sock filter is equivalent to, or better than, the other filters tested with respect to percent yield, sediment, mouth-feel, total protein and total solids in the filtered beverage. Since it is also low in cost and very simple to use, this filter will be used for developing the concept for production of soy beverage at the village level.

3. Mill for Rough Grinding of Dry Soybeans and Various Cereal Products.

The concepts for preparation of soy based products at the village level generally require that beans and other cereals be broken and/or ground before processing. Thus, a low cost mill that might be suitable for breaking or grinding raw materials for either a small industry or for village use for the general population appears highly desirable. This mill must be suitable for grinding dry materials, be of relatively high capacity and low in cost. Considering these requirements, the mill would be fabricated from mild or hardened steel and be suitable for use with dry products.

During the previous contract year, ending March 31, 1975, a canvas of manufacturers of low cost mills was made in the U.S. No effort was made outside the U.S. and it may be possible to find low cost mills that are manufactured in other countries. However, a previous survey, under a USAID contract in India, indicated that equipment made in the U.S. was generally more versatile and of lower price than similar equipment manufactured in other countries. Letters were sent to 85 companies and replies were received from 60 firms. However, of the sixty replies only about 21 appeared to be of interest or possible value for this project. Prices of these grinders or mills ranged from under $1,000.00 to nearly $7,000.00. Some items were used, rebuilt units and the most expensive were constructed of stainless steel. One mill, offered by the Decker Mfg. Co. of Rockford, Illinois, appeared to be of considerable interest. This is a typical hammermill which is equipped with six screens that range in screen size openings from 1/8" to 3/8". The unit is constructed of mild and hardened steel and, inclusive of screens, was priced at $704.00. This unit was previously ordered and received about May 1, 1976. The mill will be thoroughly evaluated for grinding all types of dry soy and cereal products during the next six months. Discussion of these findings will be included in the final research report of food processing activities which will be prepared in fall 1976.

4. Preparation of Drum-dried Soy:Cereal Flakes.

The overall aim of this research was to use whole soybeans to fortify cereals which are traditionally used in developing countries in order to increase their protein quantity and quality. Technology and materials which are suitable for developing countries were used as much as possible. The emphasis was on simplicity of process and organoleptic acceptability of product. This research was supported in part by this contract.

Research previously performed indicated that drum dried soy-cereal blends prepared from blanched whole soybeans and cereal flour or meal was organoleptically and nutritionally acceptable. This study was designed to test the possibility of using whole soy mixed with whole corn flour, whole wheat flour, or brown rice flour, rather than refined meals or white flours.

Development of a straightforward method for using the whole cereal grains should increase the yield of final product and simplify the milling technology involved. Whole grain flours often have more limited storage stability than refined flours. However, it may be possible to use soy:whole cereal products at the village level where consumption is rapid and distribution is limited to the immediate area of manufacture.

During FY 1975 preliminary trials were conducted to investigate the effect of using various fractions of milled whole corn on the organoleptic acceptability of drum dried soy:corn (1:1) flakes. Samples containing whole ground corn were generally inferior to those containing corn fractions. However, organoleptic acceptability did not appear to relate to the fiber content of the sample as might be expected. Those preliminary trials indicated the need for additional tests to determine (a) the feasibility of using whole corn and (b) processing procedures necessary to use whole corn as an ingredient and yet retain organoleptic acceptability.

Methods

Three soy:cereal weaning foods were manufactured by drum drying. The general preparation process, along with the factors investigated, are outlined in Figure 5. Bonus variety soybeans were used in this study. All soybeans were blanched in about three volumes of tap water (80 ppm hardness as Ca^{++} and 80 ppm as Na^{+}) for about 30 minutes. No studies were conducted on the effect of soaking prior to blanching or on using different blanching solutions. Some studies of this type were reported in a previous paper (Ferrier et al., 1975). After tap water blanching the soybeans were ground to a smooth slurry with a minimum amount of tap water in a Waring blender or a Reitz hammermill. Normally cereal flours were added along with sufficient water to form a smooth slurry and the soy:cereal mixture was blended together in a Waring blender for one minute at medium speed and one minute at high speed.

In some experiments selected soy:cereal slurries were gelatinized by heating slowly and carefully to 81°C. The mixture must be carefully and rapidly stirred in order to prevent uneven heating or burning. In one experiment, bicarbonate solutions in softened water were added to the soy slurry prior to addition of the cereal flour.

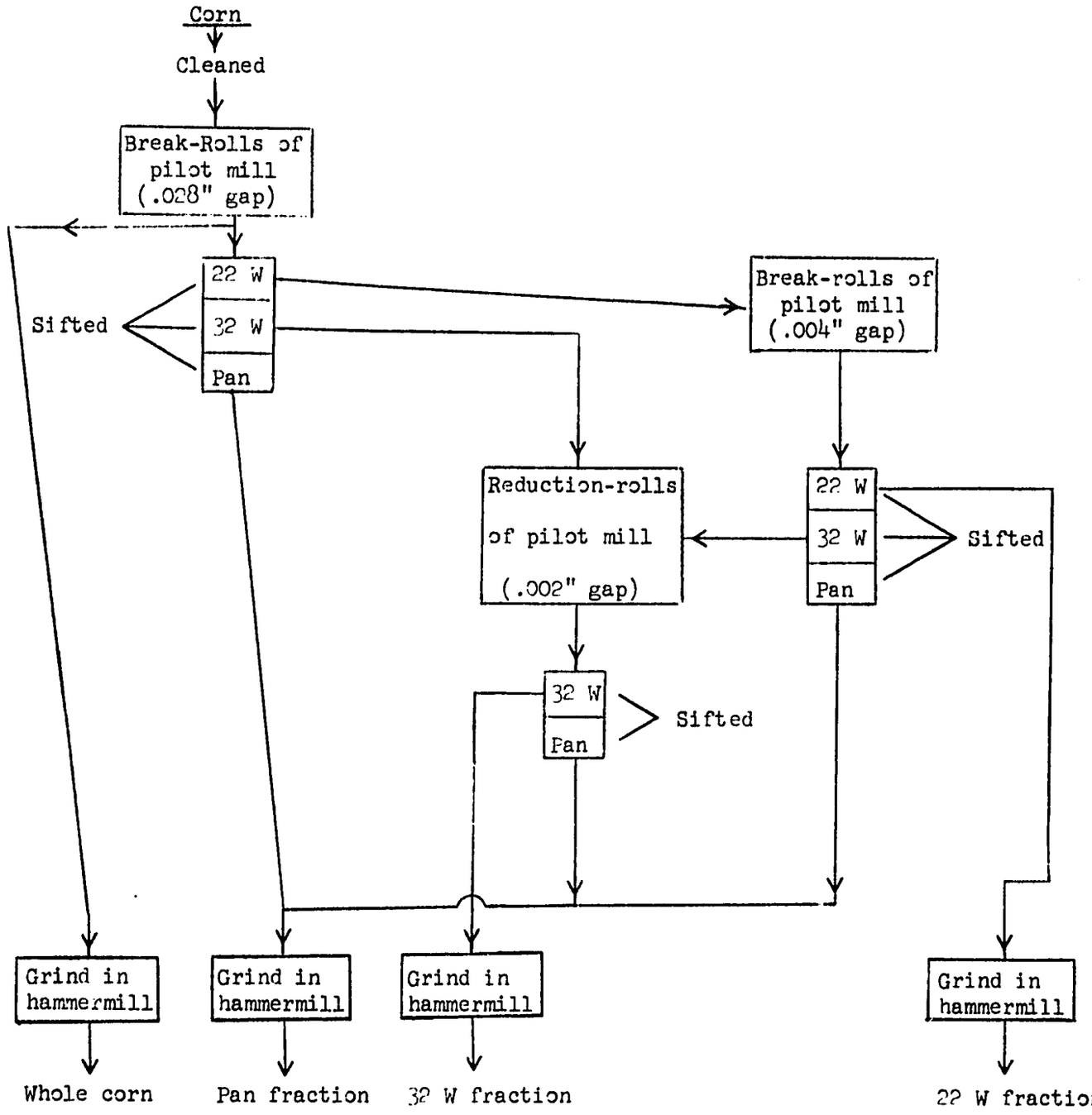
Whole corn was milled and fractionated as outlined in Figure 6, to produce four corn fractions, (1) ground whole corn, (2) the fraction retained on a 22 wire mesh screen, (3) the fraction retained on a 32 wire mesh screen, and (4) the fraction passing through a 32 wire mesh screen (pan fraction). Each fraction was further ground through a hammermill in order to equalize particle size.

Whole wheat flour was purchased locally and used in that form. Brown rice was purchased locally and ground in a hammermill (0.023" screen) prior to use. The cereal flours, along with additional water were added to the soy slurries as outlined in Figure 5.

Figure 5. PREPARATION OF DRUM-DRIED SOY:CEREAL FLAKES

Process	Variables tested
Clean whole soybeans	Use of raw soy flour rather than whole beans
Blanch in Boiling tap water	
Drain. Grind in Waring blender with tap water or bicarbonate solution in soft water	$NaHCO_3$ concentration Use of NH_4HCO_3 instead of $NaHCO_3$
Add cereal flour and blend	Fraction of milled corn Soy:cereal ratio
Gelatinize (optional)	Gelatinization
Grind to smooth slurry (20% solids) in Reitz mill using 0.023" screen	
Drum Dry (4-5% Moisture)	

Figure 6. PREPARATION OF MILLED CORN FRACTIONS



The soy:cereal ratio and selected processing steps were altered in order to observe the effects on the drum-dried product. Organoleptic characteristics studied were flavor (evaluation of the characteristic flavor of the cereal), off-flavor (bitterness, soapiness, etc.,) color, texture (softness of particles and smoothness) and "hang-up" (sticking of the particles in the mouth and throat). Chemical composition and nutritional evaluations are presently being determined.

Effect of Corn Fraction

Drum dried soy-corn mixtures (3:7 ratio) were prepared using the four different corn fractions (Figure 6). The effects of corn fraction on organoleptic hang-up and texture were evaluated and the results are shown in Table 2. They show that the pan fraction of corn resulted in a product that was significantly better than any other fraction in both hang-up and texture ($P<0.005$). This fraction had the lowest fiber content. The high correlation found between fiber content and hang-up ($r = .89$), and fiber content and texture ($r = .91$), would seem to implicate fiber as a major cause of the hang-up problems. Hang-up and particle softness improved substantially as the fractions contained less hull material. This was expected since the corn hull is known to be tough and difficult to grind. However, it must be noted that equally good correlations were found between protein content and hang-up ($r = .79$), and protein content and texture ($r = .99$). The exact nature of the above cause and effect relationship needs further investigation. Additional research is also needed to try to reduce the hang-up problem that is associated with the corn hull.

Thus, the pan fraction of corn was preferable based on organoleptic and partial nutritional data. Increasing content of the corn hull, by using other corn fractions, decreased acceptability of the products.

Optimum Soy-Cereal Ratio

Mixtures of soy with whole corn flour, whole-wheat flour, or parboiled rice flour in ratios from 0:100 to 50:50 (soy-cereal) were prepared by the process shown in Figure 5. The flakes were rehydrated to a similar consistency for each product prior to organoleptic tests for flavor, color smoothness and hang-up. The results are shown graphically in Figures 7, 8 and 9. In general there was a decrease in organoleptic scores with increase in soy content. Up to 20% soy could be tolerated in soy-corn mixtures without significant loss of the characteristic flavor of corn. Hang-up increased with greater soy content. For rice products, up to 20% soy could be added with no effect on flavor, color, hang-up or texture; further additions of soy lowered the organoleptic scores.

The data obtained for whole-wheat-soy mixtures indicate a possible lack of compatibility between the two components (Figure 9), or perhaps a need for different processing methods than those used for corn and rice. An analysis of variance indicated a significant ($P>0.001$) drop in all organoleptic scores by addition of 20% or more soy to whole wheat flour. All soy-wheat samples had a distinctly rancid and/or metallic taste.

TABLE 2. EFFECT OF CORN FRACTIONS ON HANG-UP AND TEXTURE OF DRUM-DRIED SOY:CORN (3:7) FLAKES

Corn flour fraction	% Fiber	% Protein	Hang-up	Texture
22 W	3.1	10.2	3.8	3.6
32 W	1.6	9.2	4.6	---
Pan	0.7	6.8	7.0	6.1
Whole Corn	2.3	8.8	5.0	4.9

Note: Soy-cereal mixtures were not gelatinized; no bicarbonate solution was used.
Mean organoleptic scores based on 9-point hedonic scale. For hang-up, 9 = no hang-up; 1 = an extremely large amount of hang-up. For texture, 9 = extremely desirable texture, i.e., slightly grainy, tender particles; 1 = extremely undesirable, e.g., gritty. In each case, 5 = barely acceptable.

The results obtained in these experiments with drum-dried soy-whole-wheat flakes were not expected. Previous experiments demonstrated that drum-dried soy:wheat mixtures prepared using white (refined) wheat flour had a highly desirable taste, texture and appearance. In other experiments, soy: wheat mixtures made by extruding soy flour and whole-wheat flour (atta) had desirable organoleptic qualities and storage stability. Further experiments will be carried out in the near future to clarify the situation and/or improve the processing methods for preparing drum-dried soy-wheat flakes.

Note that the soy:cereal samples which contain 30% soy received unexpectedly low scores. These samples were stored at room temperature for 3-4 weeks. All other samples were prepared shortly before organoleptic analysis. Thus, storage stability may be a problem which needs further investigation.

In summary, it appears that, up to 20% soy could be added to corn and rice before panelists could distinguish them from the all-cereal product. Hang-up was noticed at that level with corn, although no panelist rated it objectionable. The soy-whole wheat mixtures must be studied further.

Effect of Gelatinization

Table 3 shows that gelatinization improved the softness and reduced hang-up of whole corn samples but apparently increased hang-up when the pan fraction of corn was used. The reason for this is not clear.

The effect of gelatinization on soy-rice and soy-wheat mixtures was measured using triangle tests. Almost all panelists could pick the odd sample in the gelatinized versus ungelatinized triangle tests. Unlike the data for soy-corn, panelists had no apparent preference for either gelatinized or ungelatinized samples of soy-rice or soy wheat. However, the panelists were consistent in their preferences, i.e., the same panelists preferred the gelatinized version of all four samples, Table 4, indicating a variation among panelists, rather than among samples.

Gelatinization also had beneficial effects. It prevented the rice from settling out in the soy-rice mixtures and resulted in a more uniform slurry through the Reitz mill. Gelatinized samples also tended to form stronger, more continuous sheets as they were removed from the drum dryer.

In summary, the taste panel, as a whole, displayed no preference between gelatinized soy:rice and soy:wheat products although individual panelists could detect the difference between them. Panelists displayed a preference for gelatinized soy:whole corn products and for ungelatinized soy: corn prepared from the pan corn fraction.

Effect of Bicarbonate Addition Before Drum-Drying

Attempts were made to reduce the hang-up and improve the smoothness of the soy-cereal mixtures by using bicarbonate solutions instead of tap water to prepare the soybean or soy:cereal slurries. Bicarbonate is known to improve the texture of soybean when used during soaking and cooking. It was thought that it might also have a beneficial effect on the texture of the corn hull.

FIGURE 7. ORGANOLEPTIC SCORES FOR DIFFERENT RATIOS OF DRUM DRIED SOY:WHOLE CORN FLAKES

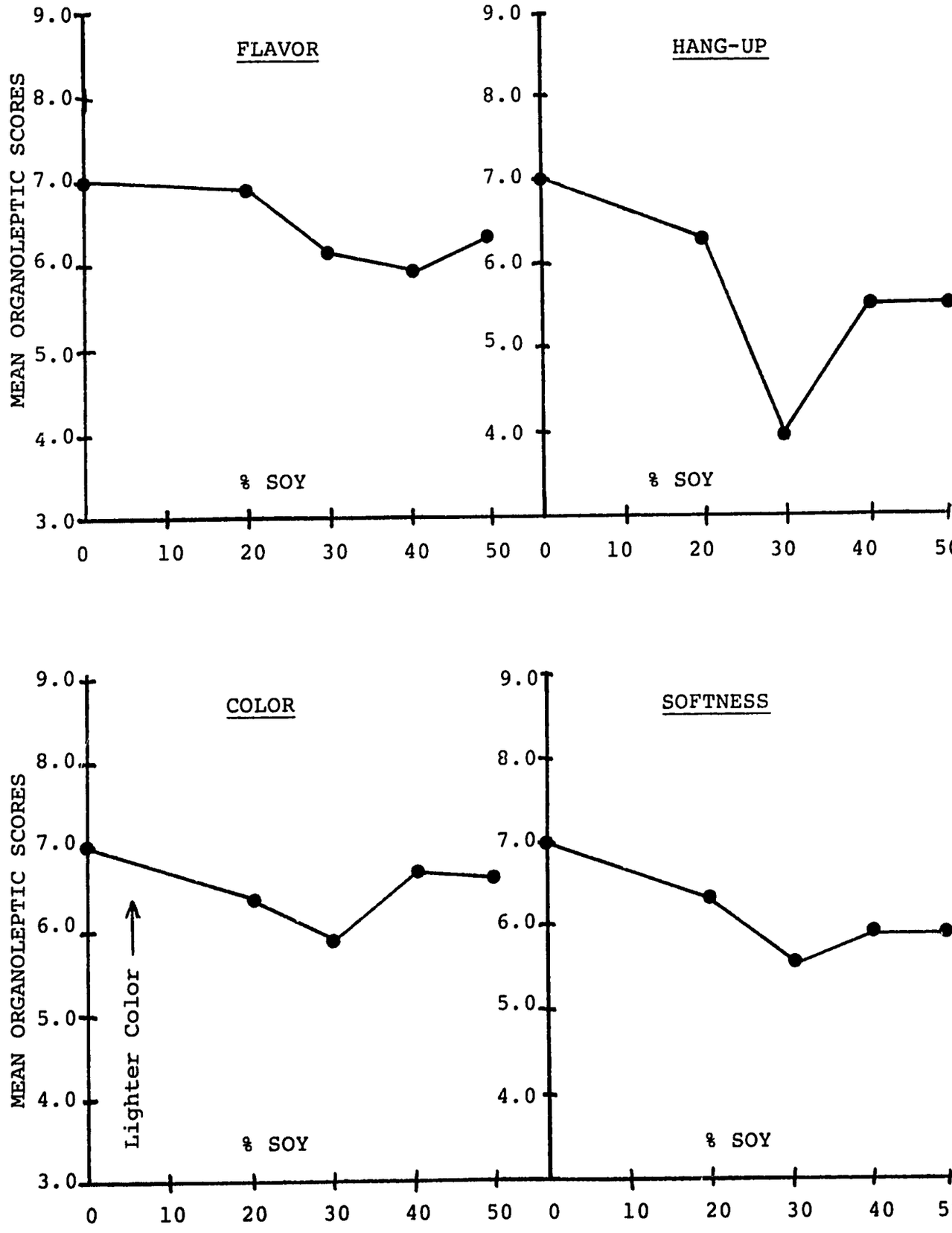


FIGURE 8. ORGANOLEPTIC SCORES FOR DIFFERENT RATIOS OF DRUM DRIED SOY:BROWN RICE FLAKES

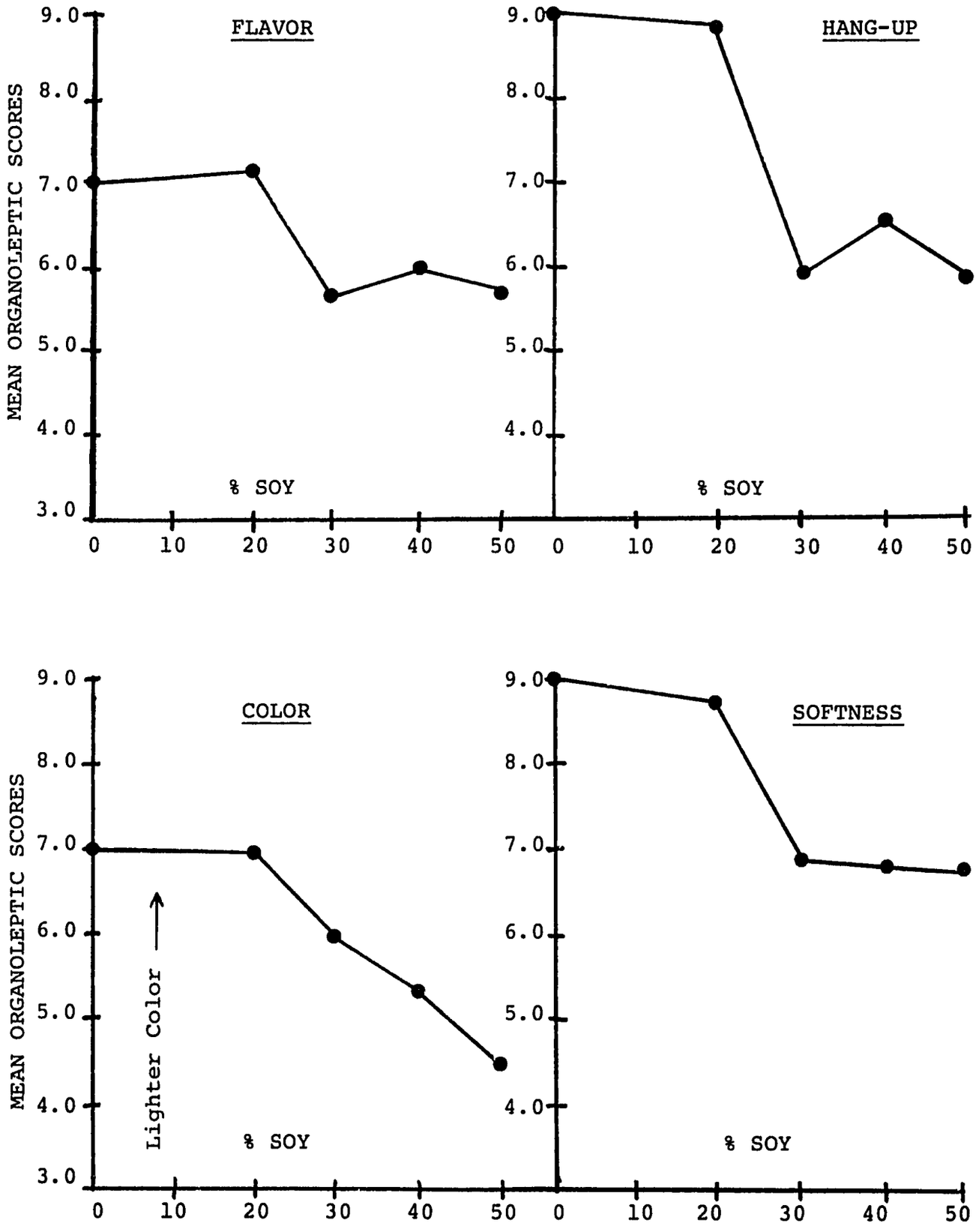


FIGURE 9. ORGANOLEPTIC SCORES FOR DIFFERENT RATIOS OF DRUM DRIED SOY:WHOLE WHEAT FLAKES

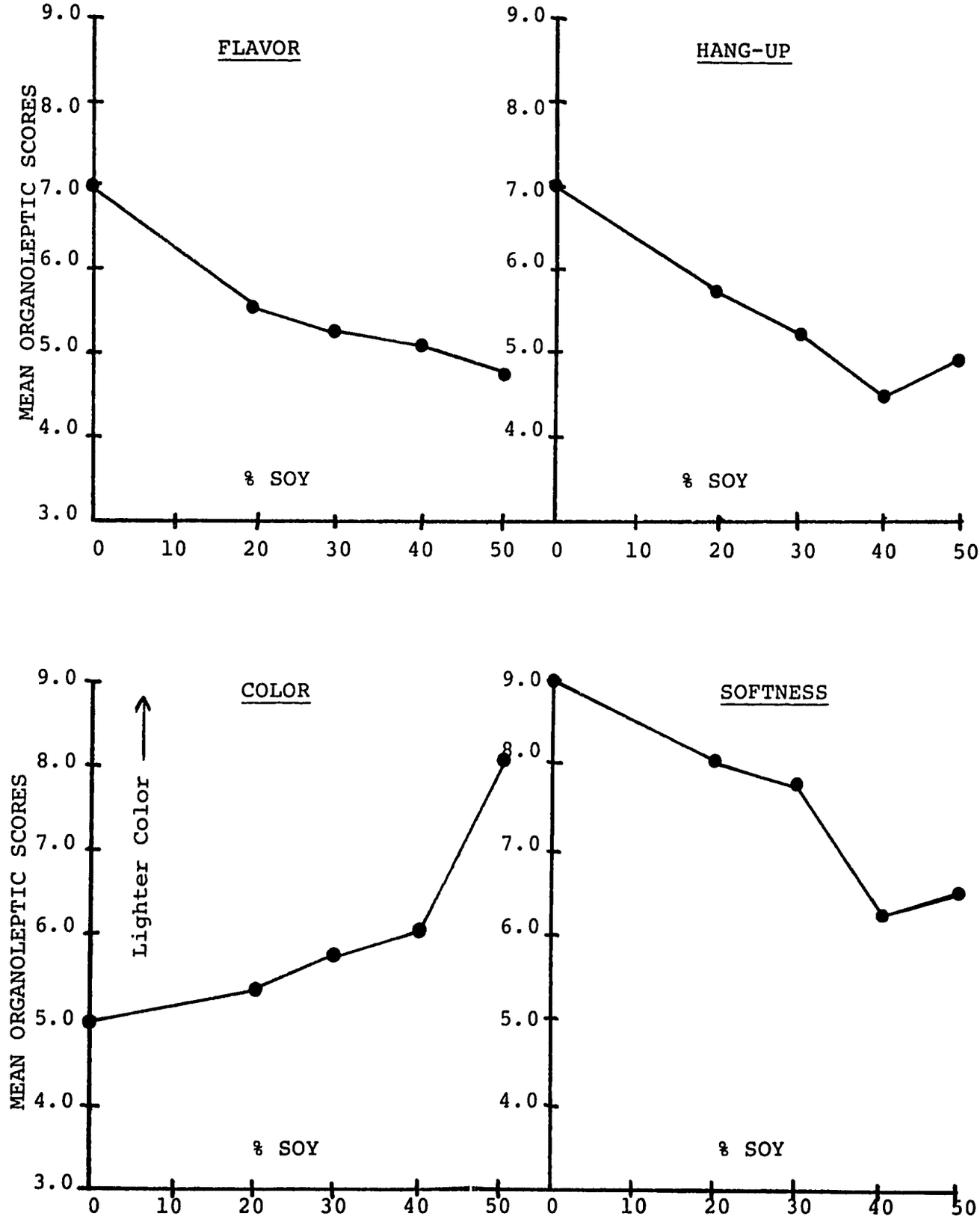


TABLE 3. EFFECT OF GELATINIZATION AND CORN FRACTION ON MOUTH-FEEL OF DRUM-DRIED FLAKES

Fraction	Gelatinization	Mean Organoleptic Scores*		
		Hang-up	Softness	Flavor
Pan	-	7.2	7.3	5.8
Pan	+	6.7	8.2	6.6
Whole	-	4.7	4.2	6.2
Whole	+	5.2	6.5	5.4

Note: No bicarbonate solutions were used.

* Mean organoleptic scores based on a 9-point hedonic scale. For hang-up, 9 = no hang-up: 1 = extreme hang-up. For softness, 9 = extremely soft, 1 = extremely hard particles. In each case, 5 = barely acceptable.

TABLE 4. EFFECT OF GELATINIZATION ON OVERALL ACCEPTABILITY (TRIANGLE TESTS)

Sample	Concentration of $NaHCO_3$	Number of Panelists	Number that could tell the difference	Number preferring gelled sample*
Soy-Rice	0.0	7	6	3
	0.05%	7	6	3
Soy-Wheat	0	7	7	3
	0.05%	7	6	3

* Among those that could tell the difference.

To determine the maximum level of bicarbonate that could be added, various concentrations of bicarbonate were added along with the cereal flours and the final product was evaluated organoleptically. (Table 5 and Table 6). Data in Table 5 indicates that no off-flavors could be detected up to 0.1% sodium bicarbonate. Above 0.1% sodium bicarbonate the off-flavor was most frequently described as "soapiness", most likely to residual bicarbonate ions or possibly due to the interaction of sodium ions and lipids. A distinct darkening of the product at the 0.5% level was also noted similar to that obtained by Ferrier et al., (12). A sodium bicarbonate concentration of 0.05% was used in all subsequent experiments which included sodium bicarbonate solution.

An attempt was made to avoid the "soapy" off-flavor by substituting ammonium bicarbonate for the sodium bicarbonate. Results for hang-up and off-flavor are shown in Table 6. No statistically significant differences were found among any of the samples, and an ammonium bicarbonate concentration of up to 5.0% could be tolerated without appreciable off-flavor. No soapiness was detected at any level of ammonium bicarbonate used and the data indicates, Table 6, that use of 0.1% ammonium bicarbonate appeared optimal.

In conclusion, it appeared that addition of sodium bicarbonate during preparation of the slurry before drum drying had some beneficial effects on mouthfeel of the soy:cereal flakes. However, it must be noted that this type of technology depends on accurate addition of the correct amount of bicarbonate. Since the bicarbonate is retained in the product, this technique may not be suitable for village use. The usual procedure used in this laboratory is to discard the soak and blanch solutions which allows more latitude in the amount of bicarbonate added.

Use of Raw Soybean as Flour

Organoleptic tests were also conducted on the effects of using raw soybean flour rather than whole beans in stage 1 of the process outlined in Figure 5. The alternate process developed is shown in Figure 7. Whole soybeans were ground to a fine powder in a pin mill and sifted directly but slowly into boiling bicarbonate solution or boiling water. Rapid stirring while adding the powder is necessary to maximize heat transfer, to prevent the hydrophobic powder from balling and to prevent scorching. The cereal flour was thoroughly mixed in cold solution before adding to the soybean slurry to prevent localized and uneven gelation that would otherwise occur if the cereal was added directly to the hot soy suspension. Table 7 shows that there was no effect on overall organoleptic scores whether soy was used as a flour or in the whole bean form.

This process of using raw soybean flour, which is outlined in Figure 7, should be considered for the following reasons:

1. Possibly the same mill that would be required to grind corn could also be used to grind soybeans into a flour, thus saving on capital expenses.

2. Blanching whole soybeans and discarding the blanch water results in a loss of some nutrients. Direct addition of soybean flour into boiling bicarbonate solution prevents off-flavors from developing and reduces loss of nutrients from the system.

TABLE 5. EFFECT OF ADDITION OF SODIUM BICARBONATE TO THE SOY SLURRY ALONG WITH THE CORN FLOUR

%$NaHCO_3$ Soln.	Final concentration of $NaHCO_3$, mg/gm product	Off-flavor score*
0.00	0.0	5.0
0.05	2.5	7.3
0.10	5.0	5.6
0.50	25.0	1.6

* Based on a 9-point hedonic scale: 1 = High off-flavor, 9 = no off-flavor, 5 = barely acceptable.

TABLE 6. EFFECT OF ADDITION OF AMMONIUM BICARBONATE TO THE SOY SLURRY ALONG WITH THE CORN FLOUR

% NH_4HCO_3 Soln.	Final concentration of NH_4HCO_3 mg/gm product	Off-flavor*	Hang-up**
0.00	0.0	5.0	5.0
0.05	2.5	6.0	5.3
0.10	5.0	7.9	6.1
1.00	50.0	5.9	5.4
5.00	250.0	5.2	4.9

* Based on a 9 point hedonic scale
1 = Strong off-flavor, 9 = No off-flavor

** Based on a 9 point hedonic scale
1 = An extremely large amount of hang-up, 9 = No hang-up,
5 = barely acceptable.

3. Since the soy flour has a vastly greater surface area than the bean, it might presumably be easier to inactivate trypsin inhibitor. This could save energy costs and reduce denaturation of the proteins. However, preliminary experimental data suggests that trypsin inhibitor is not quickly destroyed and the kinetics of inhibitor destruction must be studied further if the flour process is to be recommended.

4. Since both soy and cereal are in the flour form, the use of a Reitz mill for grinding the soy:cereal slurry may not be necessary.

In summary, use of raw soybean flour appears to be a possible alternate method. More research needs to be carried out regarding suitable equipment and technology for use at the village level.

5. Effect of Variety on Tenderness of Cooked Whole Soybeans.

Experiments reported for FY 1975 using eight varieties of soybeans indicated that the tenderness of cooked whole soybeans was substantially affected by the solutions used for soaking and cooking, by soaking before cooking, and by the variety of soybean. During FY 1976, cooking tials were carried out on 28 varieties of soybeans, mostly U.S. varieties used in INTSOY trials. Four combinations of soaking and cooking were tested in order to determine the effect of different processing methods on tenderness. About 20 physical and chemical measurements were made on each variety of soybeans in order to find some factor(s) which may be used to predict the tenderness of cooked whole soybeans.

Methods

Twenty-eight varieties of soybeans from the 1974 crop (Table 8) were soaked and cooked using four methods as outlined in Table 9. Triplicate 100 g samples of dry, mature whole soybeans were used in soaking, cooking, tenderness and organoleptic trials. U.S. varieties of soybeans were supplied by Dr. D. K. Whigham, INTSOY. All solutions, including tap water, were adjusted to pH 7.5 with NaOH or HCl. After soaking, the soaking solutions were discarded and fresh solutions were added for blanching. The soybeans were cooked and tenderness was determined using a LEE-Kramer shear press. Tenderness data was evaluated statistically using an analysis of variance and Tukey's w test.

The following physical measurements were made: volume/bean; (by displacement of water in a sealed flask); weight/bean (average of 300 beans); density before treatment; density after soaking and cooking; length, width, and depth per bean (direct measurement of 100 beans with a caliper); amount and rate of water taken up by the beans (by placing 60 g samples in water bath at 25°C and measuring weight difference at 6, 13, 20, and 36 minutes, and at 1, 1.5, 3, 4.5, and 6 hours).

Each variety was analyzed for nitrogen, fat, moisture, fiber, ash, and carbohydrate (by difference). Mean values for physical and chemical data for each variety were compared to the tenderness values determined for each variety by a regression analysis.

TABLE 7. TRIANGLE TEST OF SOY:CORN MIXTURES: USE OF FLOUR VS. WHOLE BEAN

Bicarb. Conc.	Number of Panelists	Number that could tell the difference	Number preferring flour sample*
0	7	4	3
0	7	4	2
0.05% $NaHCO_3$	7	3	0
1.0 % NH_4HCO_3	7	4	3

* Among those that could tell the difference

TABLE 8. VARIETIES TESTED AND STATE PRODUCED

Variety	State Produced	Variety	State Produced
Amsoy	Illinois	Hardee	Florida
Amsoy 71	Illinois	Hark	Illinois
Beeson	Illinois	Hodgson	Minnesota
Bonus	Illinois	Improved Pelican	Louisiana
Bossier	Louisiana	Kanrich	Illinois
Calland	Illinois	Pickett 71	Arkansas
Clark 63	Illinois	Semmes	Arkansas
Cobb	Florida	Shakkin Nashi	Japan
Coker Hampton 266A	Arkansas	Swift	Minnesota
Corsoy (1973)	Illinois	Tracy	Arkansas
Corsoy	Illinois	Woodworth	Illinois
Columbus	Kansas	Wayne	Illinois
Davis	Arkansas	Wells	Illinois
Forrest	Arkansas	Williams	Illinois

TABLE 9. EXPERIMENTAL DESIGN FOR SOAKING/BLANCHING SOYBEANS

Combination	Soak Conditions	Blanch Conditions
1.	None	Tap water, 60 min. 100°C.*
2.	None	0.5% $NaHCO_3$ " "
3.	Tap water, 20 hr, room temp	Tap water, 60 min, 100°C.
4.	0.5% $NaHCO_3$, 20 hr. room temp.	0.5% $NaHCO_3$, 60 min, 100°C.

* Tap water; 80 ppm hardness as Ca^{++}, 80 ppm Na^{+}.

TABLE 10. EFFECT OF VARIETY, SOAK, BLANCH AND SOLUTION ON TENDERNESS OF COOKED WHOLE SOYBEANS

Variety	Soak Sol'n / Blanch Sol'n	0.5% $NaHCO_3$ / 0.5% $NaHCO_3$	Tap Water / Tap Water	None / 0.5% $NaHCO_3$	None / Tap Water
		Mean Shear Press Peak Height (psi)			
Shakkin Nashi		11.97*	33.58	59.85	78.44
Corsoy (1973)		13.33	52.12	47.88	80.45
Tracy		14.55	41.97	48.03	69.85
Bonus		14.70	41.06	41.06	70.00
Calland		14.85	52.88	50.76	67.73
Hodgson		14.85	54.24	40.30	68.03
Woodworth		15.46	56.55	52.57	74.35
Amsoy 71		16.14	61.06	48.42	68.94
Wayne		16.36	61.06	48.64	81.21
Hark		16.36	52.27	45.91	70.91
Williams		16.51	58.97	45.00	77.43
Improved Pelican		16.51	48.33	42.88	68.79
Amsoy		16.67	65.91	39.85	71.06
Clark 63		16.82	72.43	49.70	66.36
Corsoy (1974)		17.27	59.09	59.55	79.85
Swift		18.79	58.33	56.36	80.60
Hardee		18.79	50.45	35.91	56.06
Columbus		18.94	57.27	53.03	66.21
Semmes		19.39	55.91	46.67	70.00
Kanrich		19.69	70.61	52.42	82.12
Wells		20.60	53.26	51.97	68.03
Beeson		20.76	68.79	63.64	91.21
Coker Hampton		21.06	49.70	48.33	63.56
Cobb		25.45	69.09	37.58	66.21
Pickett 71		25.76	63.03	48.79	82.73
Forrest		27.42	75.46	55.45	91.06
Davis		31.89	75.15	61.67	85.91
Bossier		32.58	77.81	61.97	85.76
Treatment Mean		19.1	58.4	49.8	74.4

*Five most tender varieties for each treatment are underlined.
Values are means for triplicate, 100 gm, cooked samples obtained using a LEE-Kramer shear press.

Results

Firmness (tenderness) values obtained for cooked samples of each variety of soybean are listed in Table 10. Varieties are listed in order of increasing hardness of soybeans soaked in 0.5% $NaHCO_3$ and cooked in 0.5% $NaHCO_3$. It is important to note that the different soak/cook solutions substantially alter the relative position of the most tender varieties. (The five most tender varieties are underlined for each treatment.)

All four soak/cook treatments had a different effect on the tenderness of cooked whole soybeans (Table 10). This confirmed our previous results (FY 1975) using eight varieties of soybeans. Soaking increased the mean tenderness for all varieties roughly 90%. Use of bicarbonate increased tenderness about 300% if the soybeans were soaked and cooked, and about 50% if the soybeans were cooked only (not soaked). The range of tenderness values depended on whether the soybeans were soaked or not. Soaked and cooked soybeans varied about 2.5 fold from the softest to the firmest variety. The same varieties, when not soaked, varied about 1.7-fold in softness.

Chemical and physical measurements were made on each variety of soybean. The results are listed in Tables 11-13.

Very few of the physical and chemical factors tested seemed to relate to the tenderness values of the cooked soybeans. Those factors that did were primarily related to the size of the bean, - the larger the bean, the more tender after cooking. Large seeded varieties were not always more tender. For example, Kanrich which was the second largest variety was consistently well below the mean tenderness for all varieties tested. The only other, but the best, factor that correlated was the initial moisture content of the soybeans. (Table 14)

Plots of the data that correlated well with tenderness are shown in Figures 10-14. All other data had a correlation coefficient (r) less than 0.396 with a probability P 0.05. Thus, the correlation was not statistically significant.

In summary, tenderness was increased most by soaking and cooking in bicarbonate solutions. The soak/cook treatments influenced which varieties appeared to be most tender. On variety, Bonus, was among the five most tender for three out of four treatments. Five varieties, Shakkin Nashi, Tracy, Hodgson, Hardee and Cobb were among the five most tender varieties for two out of four treatments.

Variety tests indicated that large seed size and maximum change in size during soaking and cooking resulted in greatest tenderness but this was not true for all large seeded varieties. It must be noted that these results are based only on the 1974 crop. Similar data will be gathered on the 1975 and 1976 crops in order to determine the validity of the conclusions from the 1974 crop.

TABLE 11. COMPOSITION OF 25 VARIETIES OF DRY RAW WHOLE SOYBEANS

VARIETY	% OIL	% FIBER	% PROTEIN	% ASH	% NFE*	% H_2O
AMSOY 71	22.8	5.1	35.2	4.22	23.81	8.87
CALLAND	21.6	4.6	37.1	4.30	23.90	8.50
WOODWORTH	21.3	5.6	36.8	4.37	23.65	8.28
WILLIAMS	22.4	4.7	35.3	4.35	24.79	8.46
SHAKKIN NASHI	17.8	3.8	44.6	4.26	21.78	7.76
BONUS	22.2	4.8	37.9	4.54	22.80	7.76
CORSOY (1973)	21.5		36.4	4.32		7.87
CORSOY (1974)	22.3	4.9	34.9	4.26	25.92	7.72
TRACY	15.8	4.5	40.0	3.76	28.41	7.53
PICKETT 71	19.8	4.4	38.6	4.23	25.70	7.27
BOSSIER	22.4	5.4	36.9	5.06	23.51	6.73
WELLS	22.0	4.2	36.3	4.55	25.18	7.77
COKER HAMPTON	17.5	4.3	36.9	4.09	29.96	7.25
DAVIS	20.5	4.8	38.8	3.90	25.40	6.60
COBB	22.8	5.0	34.4	4.66	26.06	7.08
HODGSON	21.5	5.1	36.8	4.23	24.47	7.90
AMSOY	22.8	4.1	34.8	4.19	26.95	7.16
IMPROVED PELICAN	19.2	4.4	40.1	4.64	24.30	7.36
SWIFT	24.5	5.1	33.8	4.16	25.44	7.00
SEMMES	19.4	4.0	37.5	3.93	28.25	6.92
HARK	22.4	4.8	35.9	4.38	25.14	7.38
HARDEE	22.8	4.9	37.0	4.81	22.74	7.75
FORREST	22.2	5.2	35.1	4.19	25.85	7.46
COLUMBUS	20.8	4.4	36.8	4.44	26.15	7.41
BEESON	22.3	4.8	36.7	4.14	25.05	7.01
KANRICH	21.7		36.5			7.66

* Nitrogen free extract

TABLE 12. PHYSICAL CHARACTERISTICS OF 25 VARIETIES OF DRY RAW WHOLE SOYBEANS

VARIETY	DENSITY	WT/BEAN GRAMS	VOL/BEAN CM^3	LENGTH CM	WIDTH CM	DEPTH CM
AMSOY 71	1.195	.165	.136	.505	.368	.439
CALLAND	1.183	.181	.153			
WOODWORTH	1.179	.158	.134			
WILLIAMS	1.193	.158	.132			
SHAKKIN NASHI	1.235	.364	.295			
BONUS	1.201	.155	.129			
CORSOY (1973)	1.207	.175	.145			
TRACY	1.217	.172	.141			
PICKETT 71	1.220	.132	.108			
BOSSIER	1.216	.135	.111	.434	.300	.396
WELLS	1.200	.152	.127	.472	.330	.414
COKER HAMPTON	1.223	.160	.131			
DAVIS	1.231	.164	.133	.472	.290	.411
COBB	1.212	.132	.109			
HODGSON	1.169	.167	.143			
AMSOY	1.214	.163	.134			
IMPROVED PELICAN	1.234	.119	.096	.434	.262	.366
SWIFT	1.202	.164	.136			
SEMMES	1.209	.147	.122	.483	.328	.432
HARK	1.208	.150	.124	.493	.300	.414
HARDEE	1.193	.152	.127	.508	.290	.429
FORREST	1.208	.138	.114	.422	.312	.406
CORSOY (1974)	1.212	.182	.150			
COLUMBUS	1.095	.158	.144			
BEESON	1.202	.185	.154	.538	.345	.442
KANRICH		.303		.868	.658	.815

TABLE 13. SOAKING/COOKING CHANGES OF 24 VARIETIES OF SOYBEANS

VARIETY	CHANGE IN WEIGHT/BEAN (DRY TO COOKED STATE) (g)	% CHANGE IN WEIGHT (DRY TO COOKED STATE)	% CHANGE IN WEIGHT DURING SOAKING IN 0.5% $NaHCO_3$ AT 25°C.	
			6 HR.	24 HR.
AMSOY 71	.187	114.84	97.08	101.77
CALLAND	.214	118.23	101.86	110.46
WOODWORTH	.183	115.82	96.00	104.92
WILLIAMS	.150	94.94	77.49	84.72
SHAKKIN NASHI	.456	125.27	95.14	120.42
BONUS	.173	111.61	97.44	109.41
CORSOY (1973)	.203	116.00	98.12	105.08
TRACY	.203	118.02	100.37	111.70
PICKETT 71	.143	108.33	95.77	103.90
BOSSIER	.148	109.63	89.75	101.93
WELLS	.182	119.74	97.98	115.91
COKER HAMPTON	.191	119.74	97.51	111.04
DAVIS	.187	114.02	101.16	109.46
COBB	.132	100.00	89.62	87.40
HODGSON	.163	97.60	86.88	89.75
AMSOY	.174	106.75	93.08	101.98
IMPROVED PELICAN	.130	109.24	91.95	98.98
SWIFT	.193	117.68	103.52	117.09
SEMMES	.147	100.00	89.61	99.46
HARK	.182	121.33	105.97	116.73
HARDEE	.170	111.84	99.30	107.44
FORREST	.158	114.49	98.14	111.40
CORSOY (1974)	.209	114.84	101.22	108.55
COLUMBUS	.186	117.72	103.75	115.68
BEESON	.216	116.76	101.74	117.00

Note: Soybeans were soaked and cooked in 0.5% $NaHCO_3$, pH 7.5.

TABLE 14. SIGNIFICANCE OF FACTORS AFFECTING TENDERNESS.

FACTOR	REGRESSION COEFFICIENT (r)	PROBABILITY (P)*
% Moisture	0.53	.01
Weight/bean	0.41	.05
Volume/bean	0.41	.05
Cooked weight/bean	0.40	.05
Cooked volume/bean	0.40	.05

* Significance was determined by doing a regression analysis.

FIGURE 10. EFFECT OF INITIAL MOISTURE CONTENT ON FIRMNESS OF DIFFERENT VARIETIES OF COOKED WHOLE SOYBEANS

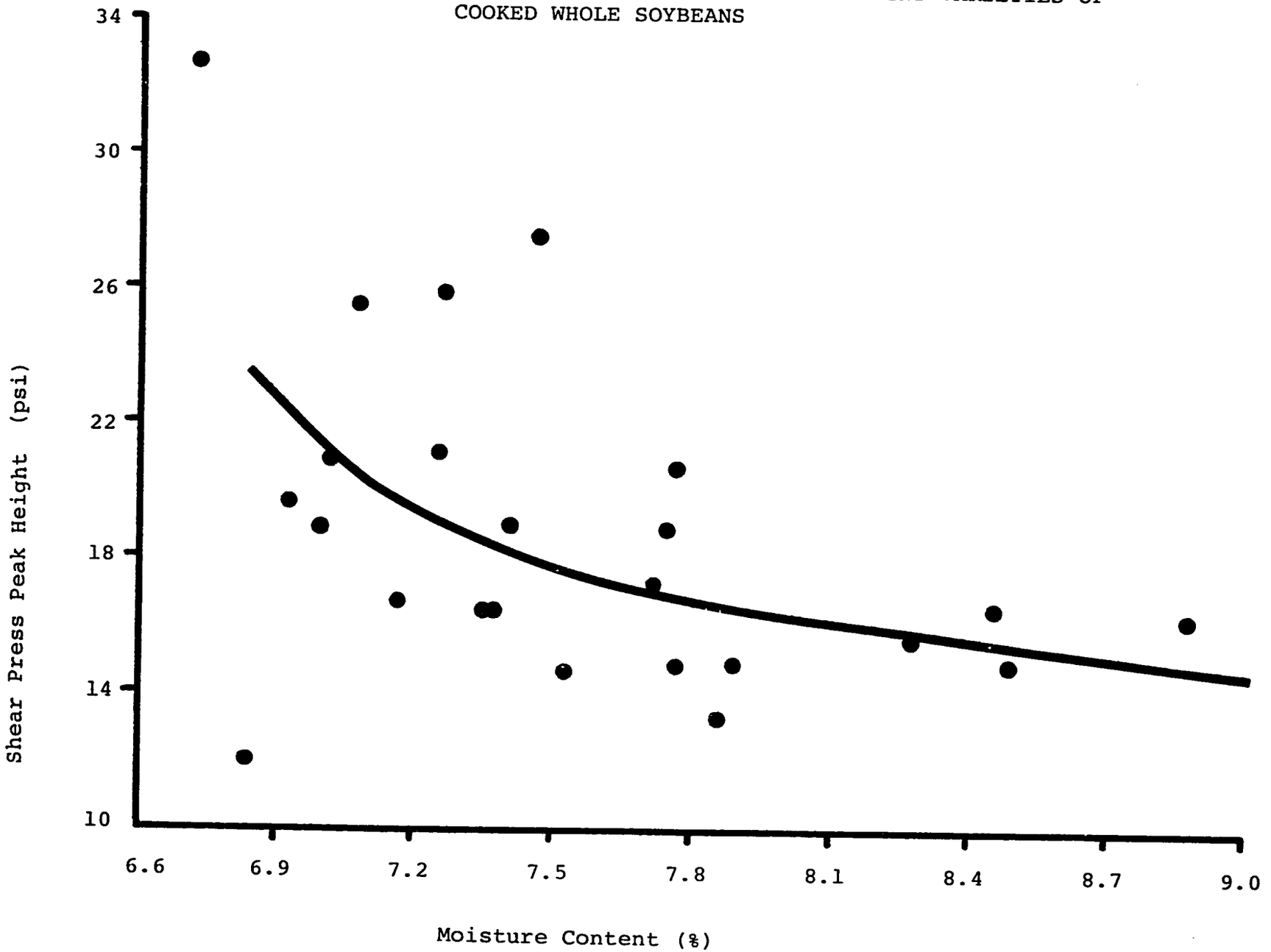


FIGURE 11. EFFECT OF SEED WEIGHT ON FIRMNESS OF DIFFERENT VARIETIES OF COOKED WHOLE SOYBEANS

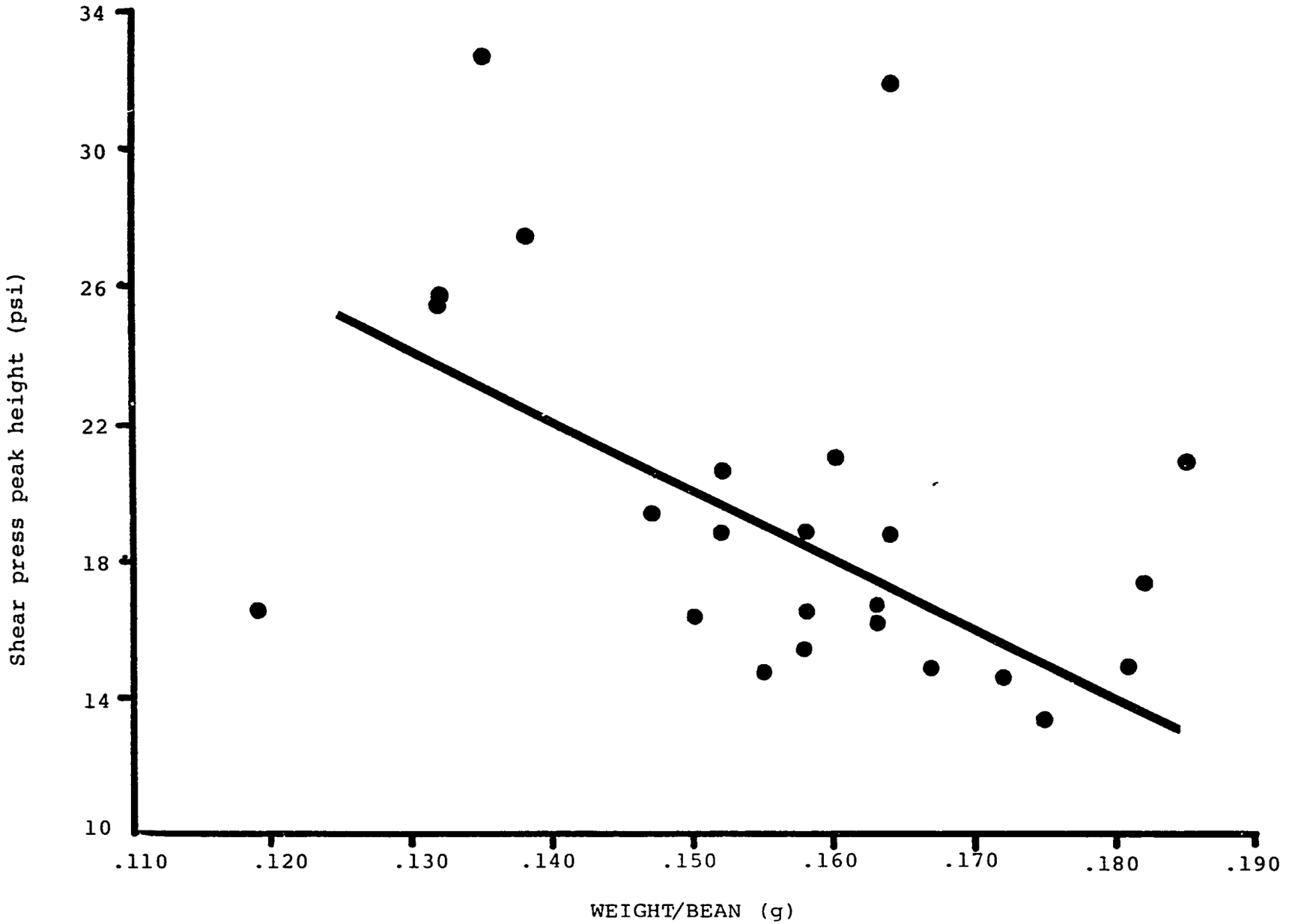


FIGURE 12. EFFECT OF BEAN VOLUME ON FIRMNESS OF DIFFERENT VARIETIES OF COOKED WHOLE SOYBEANS

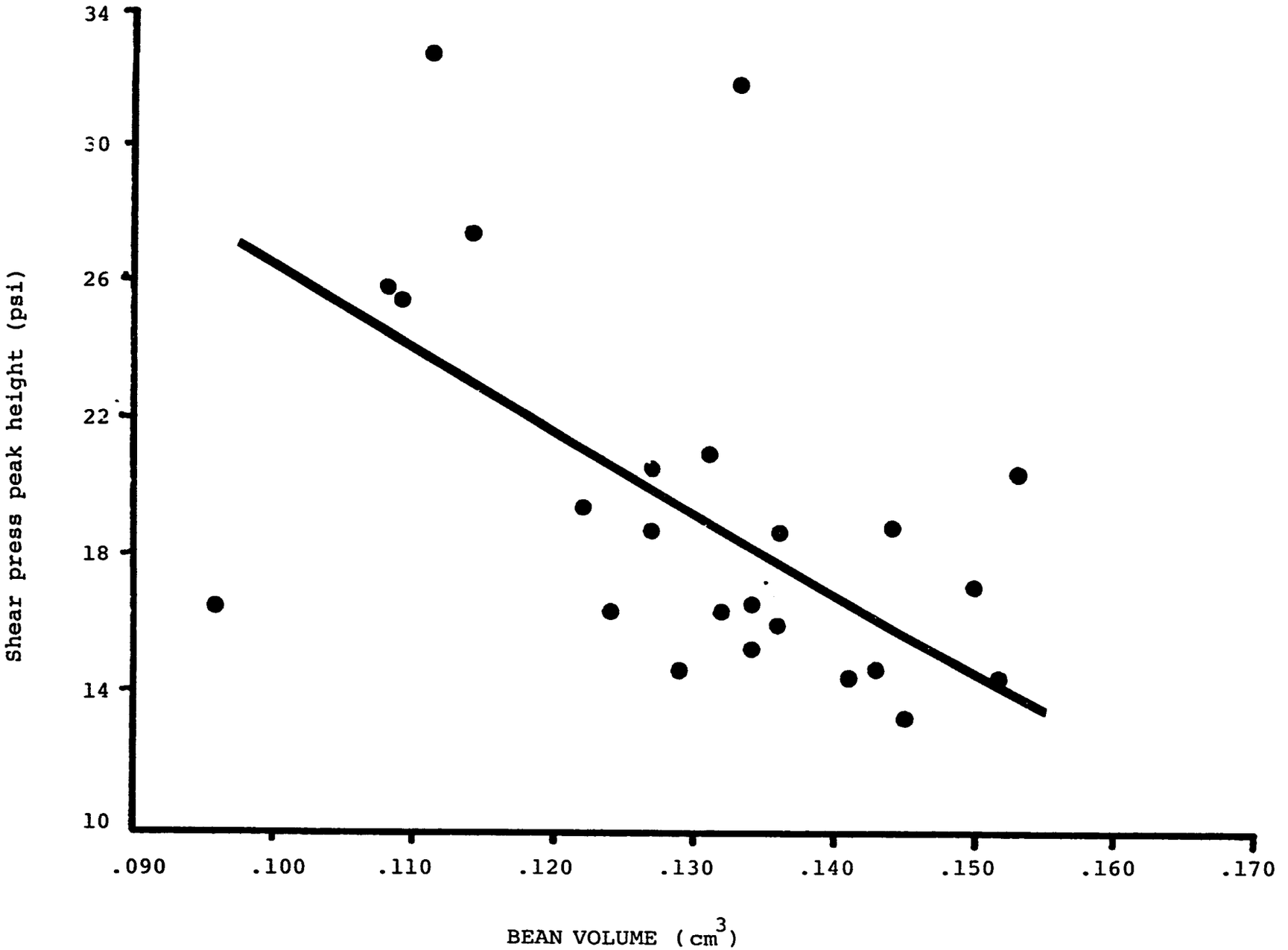


FIGURE 15. CORRELATION OF COOKED WEIGHT/BEAN ON TENDERNESS OF DIFFERENT VARIETIES OF COOKED WHOLE SOYBEANS

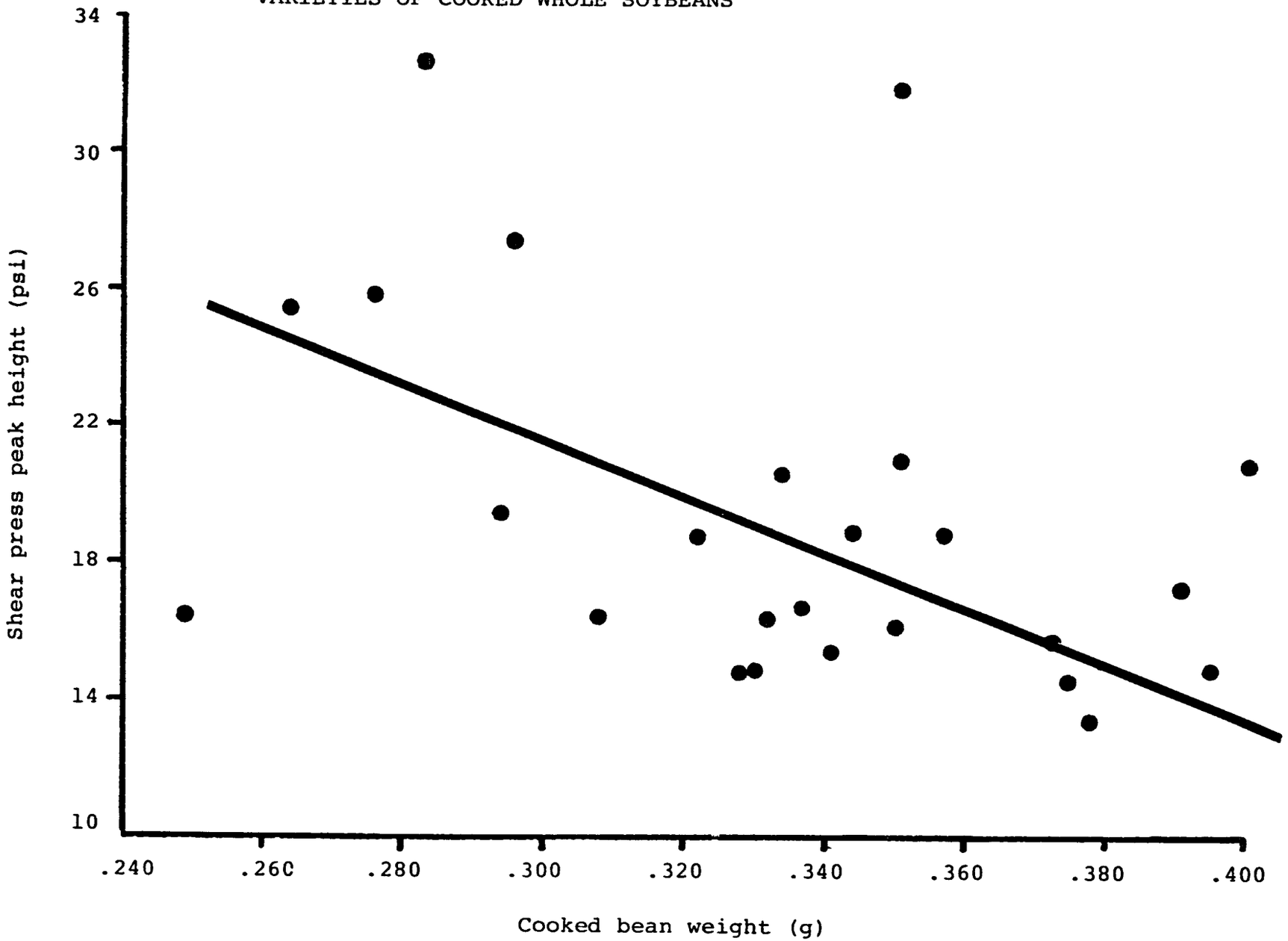
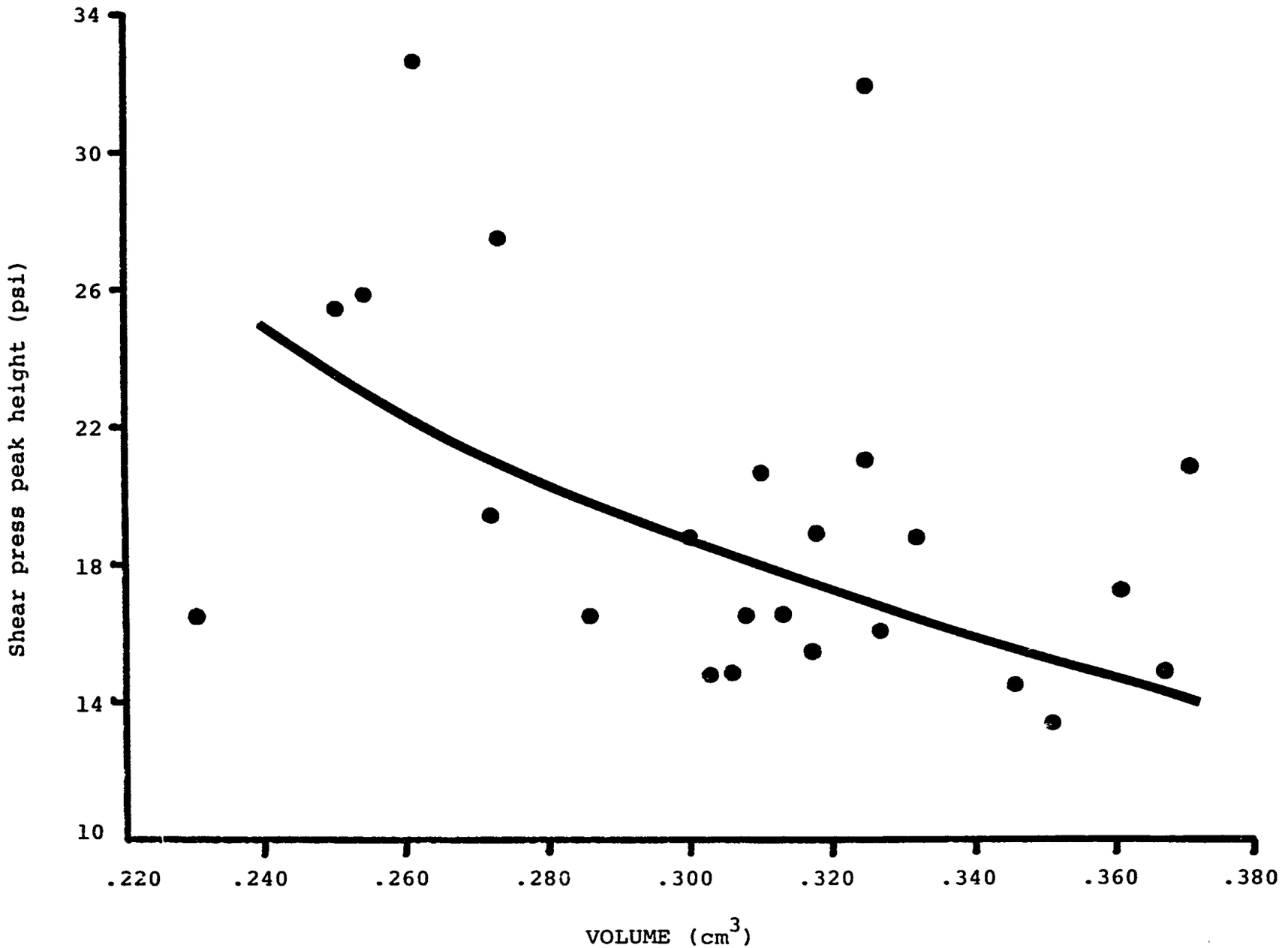


FIGURE 14. CORRELATION OF COOKED VOLUME/BEAN ON TENDERNESS OF DIFFERENT VARIETIES OF COOKED WHOLE SOYBEANS



APPENDIX V

PROJECT OUTPUT

Soybean Variety Development

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