PN-AAG-959

DEVELOPMENT OF IMPROVED VARIETIES OF SOYBEANS SUPPORTING CULTURAL AND MARKETING PRACTICES FOR PRODUCTION IN THE TROPICS AND INFORMATION DELIVERY SYSTEMS

Annual Report on
Contract AID/TA-C-1294
April 1, 1977 to March 31, 1978

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

Table of Contents

Page

Report Summary 1

A. Statistical Summary 1
B. Narrative Summary of Accomplishments 1

Report of Progress 3

A. Objectives 3
B. Background 3
C. Accomplishment by Objectives 4

1. Development of Improved Genetic Materials for Use in LDC Breeding Programs 4
2. Improvement of Technologies for Rhizobium Production and Management in Tropical Ecologies 9
3. Management and Expansion of the Knowledge Base in Soybean Production, Protection and Utilization 13
4. Improvement of the Knowledge Useful for Disease Control in Soybeans 16
5. Development of Model Insect, Weed and Disease Control Management Systems Which can be Adapted or Modified for Specific Environments 22
6. Development of Improved Seed Storage Technology 23

D. Ancillary Activities 24
E. Administration, Staff and Budget 24

Appendices:

I. Report of William H. Judy, Associate Professor of Agronomy and H. J. Hill, Assistant Agronomist 29
II. Report of Robert M. Goodman, Assistant Professor of Plant Pathology 73
III. Report of M. E. Irwin, Assistant Professor of Agricultural Entomology 104
IV. Report of A. I. Nelson and L. S. Wei, Professors of Food Science 125
V. Report of R. Stewart Smith, Assistant Professor of Soil Microbiology 141
VI. Report of Jenny Kogan, Research Assistant in Economic Entomology Section, Illinois Natural History Survey 162
VII. Report of John Bouseman, Assistant Entomologist, Economic Entomology Section, Illinois Natural History Survey 173
VIII. Report of James B. Sinclair, Professor of Plant Pathology . 176
IX. Report of Errol D. Rodda, Professor of Agricultural Engineering 186

REPORT SUMMARY

A. Statistical Summary

1. Project Title and Contract Number: Development of Improved Varieties of Soybeans and Supporting Cultural and Marketing Practices for Production in the Tropics and Information Delivery Systems - AID/ta-c-1294.

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, 1976 - March 31, 1979

4. Period Covered by Report: April 1, 1977 - March 31, 1978

5. Total AID Funding of Contract to Date: $2,085,855

6. Total Expenditures for Report Period: $632,740

B. Narrative Summary of Accomplishments

Accelerated progress was made toward the development and exploitation of the inherent potential of the soybean as an efficient source of high quality protein and edible oil for the diets of both the rural and urban poor in developing countries. An array of trials has been developed to identify, evaluate and speed the process of adoption of improved soybean varieties by producers in tropical and subtropical areas. Substantial attention is being given to cultivars which exhibit resistance to diseases and insects. The search continued for soybean varieties exhibiting superior cooking qualities.

Work got underway in mid 1977 in soybean microbiology at Puerto Rico. A collection of *Rhizobium japonicum* has been made and five separate research projects have been initiated on nodulation parameters, number of *R. japonicum* necessary to establish satisfactory nodulation, screening of *R. japonicum* strains for growth at elevated temperatures, evaluation of inoculant carriers for the tropics, and screening for nitrogen fixation on eight sorghum hybrid lines. The three basic information systems, TAXIR, SIRIC, and IRCSA, were utilized in the management and dissemination of knowledge about soybean production, protection and utilization. Two new titles in the INTSOY publication series were issued, "Rust of Soybean: The Problem and Research Needs" - Number 12, and "Pedigrees of Soybean Cultivars Released in the United States and Canada" - Number 13. In addition, the manuscript for Number 14 "Whole Soybean Foods for Home and Village Use," was completed and will be published during the next contract year.

Work in disease control continued to feature the collaborative work of viral and fungal plant pathologists and entomologists. Soybean mosaic virus, cowpea mosaic virus, bean golden mosaic virus, Bacillus subtilis, Phomopsis sojae and virus vector studies were the focus of investigations in this area.

Progress continued in the development of model insect control management systems. Studies on thrips, Orius and the velvetbean caterpillar were continued. Colleagues at the University of Puerto Rico, Mayaguez Campus, are taking leadership of weed control studies.

Cooperative work between UIUC and UPR/MC agricultural engineers confirmed that reducing seed moisture content and maintaining it during storage were essential ingredients for preserving soybean seed quality at an acceptable level. Follow up work on studies reported in last year's annual report was conducted. The INTSOY research staff engaged in a number of ancillary activities relevant to the general objectives of the research project and contributory to the development of response capabilities in soybean production, protection and use. These activities included participation in sponsored training courses, conducting of seminars and providing advisory services to LDC's under agency task orders, and supplying information by dissemination of publications and newsletters and response to inquiries by correspondence.

REPORT OF PROGRESS

A. Objectives

The purpose to which this contract contributes is the development and exploitation of the inherent potential of the soybean as an efficient source of high quality, edible oil and high quality protein for diets of both the rural and urban poor. Six continuing objectives addressed the generation of knowledge and development of technology. They include:

1. Development of improved genetic materials for use in LDC soybean breeding programs

2. Improvement of technologies for *Rhizobium* production and management in tropical ecologies

3. Management and expansion of the knowledge base in soybean production, protection and utilization

4. Improvement of the knowledge useful for disease control in soybeans

5. Development of model insect, weed and disease control management systems which can be adapted or modified for specific tropical and subtropical environments

6. Development of improved seed storage technology

B. Background

This report concentrates on progress made in the second year of a three-year research project. During the first year substantial progress was made toward each of the six contract objectives enumerated above and a seventh objective, phasing out of previous home processing activities of soybeans, was accomplished. Work continued on developing improved genetic materials for use in LDC breeding programs. Research on *Rhizobium* production and management was initiated following up on recruitment, planning and site selection during the first contract year. Three information systems, TAXIR, SIRIC, and IRCSA were utilized in the management and dissemination of knowledge on soybean production, protection and utilization.

The INTSOY Newsletter continued to be well received by a general audience wanting to know more about soybean production, protection and utilization. Additions were made to the INTSOY Publication Series. Studies on disease control were addressed on an interdisciplinary basis with plant pathology and entomology as the lead disciplines. Progress continued in the development of model insect, weed and disease control management systems. Leadership on weed control studies was assumed by colleagues at the University of Puerto Rico, Mayaguez Campus. Cooperative work between UIUC and UPR/MC agricultural engineers resulted in the publication of a study on improved soybean storage technology. The INTSOY research staff also

engaged in a number of ancillary activities relevant to the general objectives of the research project and contributed to the development of response capabilities in soybean production, protection and use.

C. Accomplishment by Objectives

INTSOY follows an interdisciplinary approach in addressing the objectives of the tasks it undertakes. This approach is well illustrated in the following summary reports on each of the continuing objectives. Individual researchers cooperate in addressing problems associated with interrelated objectives in a manner of operation that maximizes the limited personnel, facilities and fiscal resources available to the program. The summaries of progress on each objective are augmented by complete reports by lead scientists in the various disciplines, and their collaborators. These reports are presented as Appendices I - IX.

Objective I. Development of Improved Genetic Materials for Use in LDC Breeding Programs

A significant amount of the progress in this area was provided by the INTSOY plant breeder stationed at UPR/MC under 211(d) grant AID/CM/ta-g-73-49 and has been reported in the annual reports of that grant. Work in soybean variety development, disease and insect control, and cooking quality relating to identification of characteristics appropriate for incorporation in a breeding program are summarized below.

Soybean Variety Development. The major objectives of the soybean variety development program include selection for high stable yield and high protein per unit of land area, suitable photoperiod response, resistance to disease and insect pests that limit yield and seed quality, and wide adaptability in tropical and subtropical environments. The INTSOY plant breeder at UPR/MC evaluates the tropical and subtropical germ plasm and makes crosses between high yielding temperate and tropically adapted germ plasm. The varieties developed in this Puerto Rico program are evaluated in the Soybean Preliminary Observation Trial (SPOT) which was carried out at six locations in 1976 and at eight locations in 1977. Six varieties from the SPOT trial were selected for the 1978 International Soybean Variety Evaluation Experiments (ISVEX) trials. ISVEX provides the main thrust in the variety development work. The ISVEX trial provides an opportunity for testing the adaptation of soybean varieties under a wide range of environmental conditions in comparison with introduced and locally available cultivars in the countries where trials are conducted. This comprehensive variety testing program depends upon the voluntary collaboration of the cooperators. The varieties included in the ISVEX have varied over time. Varieties have been grouped into early, medium, and late maturing trials as a result of suggestions by cooperators and evaluation by the trial coordinator, and this procedure has worked well in the 1976, 1977, and 1978 trials.

The trial coordinator supplies the seed for all experiments except the local variety included at the option of the cooperator, and provides

inoculum, a standard set of instructions and data collection sheets. The country cooperator provides land, labor, fertilizer and management necessary for the experiment. Instructions for management and data collection are standardized and sent to each cooperator. General information returned by the cooperator includes additional details such as latitude, elevation and soil conditions, date of planting and harvesting, amount of moisture from rainfall or irrigation, fertilizer use, local varieties tested, and observations on diseases and insects. The data required to be reported for each plot by the cooperators includes yield, nodulation, days to flowering, days to maturity, plant height at maturity, estimates of lodging and shattering and seed quality. Samples of each of the varieties are also returned to INTSOY for protein and oil content analysis.

The SPOT was organized in 1975 to provide a means for evaluating the environmental response of newly-developed cultivars at a limited number of sites. These cultivars were obtained from selections in the INTSOY breeding program in Puerto Rico and from soybean breeding programs of cooperators in Asia and South America. There were six new entries in 1977 and seven new entries in 1978. The number of locations has been increased from eight in 1977 to 18 in 1978 in order to obtain a more precise evaluation of the new varieties in different environments. Five entries from the 1976 and 1977 SPOT trials were selected for inclusion in the 1978 ISVEX.

A new trial was organized to begin in 1978 to tap the pool of germ plasm being developed in country soybean programs throughout the world. The trial is called the Soybean International Experiment Variety Evaluation (SIEVE) trial. Cooperators from 15 countries contributed 48 cultivars developed to the F-6 or later stages for the 1978 trial. This collection will be evaluated at 0°, 18°, and 30° latitude. In addition to yield, observations will be made on agronomic and pest resistant characteristics of these varieties. Selections from the SIEVE trial and from the Puerto Rico breeding program will be entered in the SPOT trial. Selections will be made from the SPOT trial for inclusion in the ISVEX trial. When the system is fully operative it is estimated that a variety could move from the breeder to the farmer in a minimum of four years and that all active breeding programs in the world could contribute to the tropical and subtropical genetic improvement program. For summaries and progress reports on the 1975, 1976, 1977, and 1978 ISVEX trials and for the 1976 SPOT trial, see Appendix I.

Disease Control Through Genetic Improvement. Work continued on identification of tropically adapted soybean germ plasm resistant to soybean mosaic virus, cowpea mosaic virus and whitefly transmitted virus. In last year's annual report eight soybean lines were reported to possess resistance in field trials to the Illinois severe isolate of soybean mosaic virus (SMV). Subsequent studies in the greenhouse at Urbana revealed that certain of these lines were susceptible but difficult to inoculate or were susceptible to another isolate of the virus than that used in the first tests. Currently four lines are regarded as

possessing promising resistance or immunity to several isolates of SMV including Buffalo, PI 341.242, PI 324.068, and PI 374.193. Work during 1977-78 has been concentrated on Buffalo.

Buffalo has been used as a cultivar to test over 100 SMV isolates grouped in seven strains based on their ability to infect a range of supposedly SMV resistant cultivars. Buffalo was immune to all isolates except for two which were placed in strain G7, a strain which infected all "resistant" cultivars tested. When Buffalo was inoculated with strain G7 only about half the plants became infected. Reinoculation resulted in infection of all of the previously noninfected plants. Buffalo thus does not appear to possess any immunity to strain G7 but it is difficult to inoculate.

Buffalo is a late-maturing variety (Group VIII) and has a desirable growth habit and other agronomic characteristics which, in combination with its immunity to all but the most virulent of SMV isolates, will be of particular interest to breeders who require a tropically adapted source of SMV resistance. The cultivars Geguld and Hernon 147, the parents of Buffalo, have been tested through the courtesy of Dr. J. R. Tattersfield of Salisbury, Rhodesia who supplied seeds. Geguld was susceptible to the Illinois severe isolate (SMV-Il-S) but Hernon 147 was immune. No tests with other more virulent SMV isolates have been conducted to date on these parental cultivars. Genetic study is now underway to determine the inheritance of Buffalo's SMV resistance and to incorporate this trait into advanced tropically adapted soybean cultivars.

Several F1 plants of the cross Buffalo x Jupiter were inoculated with SMV-Il-S in the field in Puerto Rico during June, 1977. The plants were inoculated twice, once at the primary leaf stage and again two weeks later. Jupiter has been found to be susceptible to the SMV isolate used in this study. The F1 plants remained symptomless throughout the growing season. It appears, therefore, that the Buffalo source of SMV resistance is controlled by one or more dominant genes.

The three PI lines referred to above are also being tested with the seven SMV strains, but the results are not yet available.

Two experiments were conducted to screen soybean cultivars for resistance to cowpea mosaic virus (CPMV-PR) infection; one was conducted in the greenhouse at Urbana and the other in the field at Isabela, Puerto Rico. In the greenhouse experiment 112 named cultivars in maturity groups 00-IV were selected. All soybean cultivars inoculated with CPMV-PR became infected. Slight variations in symptoms were observed. Systemic symptoms observed ranged from mild to severe mosaic with severe stunting. Some cultivars showed top necrosis and growth was checked. Plants were killed within ten days after inoculation.

In a field screening trial at Isabela, Puerto Rico, 100 soybean cultivars were chosen from maturity groups V to X, including plant introductions and named cultivars. Additionally, 13 lines resistant to feeding by

beetles were included. All cultivars inoculated with CPMV-PR in this trial became infected. Symptoms were similar to those described from the greenhouse test. Systemic mosaic was common for all cultivars inoculated with some showing systemic necrosis in addition. Variations within cultivars were observed, but it was concluded that the variations observed were not due to genetic variations of the plants, but possibly due to late emergence of the plants in the field avoiding inoculation. It was also observed that CPMV-PR infection delayed maturity. Virus infected plants remained green when healthy plants in the noninoculated subplots reached maturity.

The results from both greenhouse and field screening trials are interesting in that all soybean cultivars tested were susceptible to CPMV-PR infection. In most of the cultivars severe symptoms were observed and pods were rarely produced on infected plants.

A visit was made to the soybean breeding program of the G. B. Pant University of Agriculture and Technology, Pantnagar, India in September, 1977 to observe field reactions of soybean germ plasm and advanced breeding lines resistant and immune to yellow mosaic virus. Seed of PI 171.443 supplied by the soybean breeder, Dr. B. B. Singh, has been increased for testing against the whitefly transmitted Rhynchosia mosaic and Euphorbia mosaic viruses that affect soybeans in the new world.

Further attempts were made to identify soybean germ plasm, tropically adapted and northern, with no incidence of SMV seed transmission. The entire tropically adapted soybean germ plasm was screened for the incidence of seed borne mosaic virus. These experiments began in 1976 and were partially reported in last year's annual report. Seeds from SMV-infected field grown soybeans were harvested and tested over the winter of 1976-77 for SMV seed transmission incidence. Of 400 lines tested, 98 had rates of seed transmission low enough not to be detected when seedlings emerging from 200 seeds were evaluated. These 98 lines, along with two known seed transmitters were planted at Isabela, Puerto Rico in May, 1977 and again inoculated by hand with the Illinois severe isolate of SMV. At the end of the season seeds were again harvested from SMV-infected plants and tested in the greenhouse for seed transmission. These tests are nearly complete and results indicate at least five lines with no seed transmission of SMV-Il-S. Completion of the data collection may result in one or two additions to this list.

Two types of experiments remain before this information could be used in variety improvement for tropical areas. It must be demonstrated that the seed nontransmission character is stable and inheritable. This will be tested by block testing of lines in the field, inoculating the lines with SMV and examining large numbers of progeny seed in field plots for evidence of seed transmission. Some crossing with the line showing high incidence of seed transmission will be conducted to determine if seed nontransmission is simply inherited. In a second experiment these lines will be tested with other strains of SMV to determine if lines that are seed nontransmitters of one SMV strain are also nontransmitters

of other strains. These experiments, which are time-consuming, will be initiated in the 1978-79 contract year.

Last year's annual report described the early stages of trails looking at seed transmission rates in northern germ plasm and maturity groups II and III. Thirty-five lines selected for testing during 1977-78 were chosen because they had low rates of seed transmission and because they exhibited slight, if any, seed coat discoloration (mottling) which is an undesirable symptom of the seed produced by SMV-infected plants. Results this year showed that seed coat mottling cannot be selected against in this type of experiment. The incidence and severity of mottling was high in all lines, but the incidence of SMV seed transmission was law. Fourteen lines were identified that exhibited no evidence of SMV seed transmission from seedlings emerging from 1,000 seeds.

Further tests with Group II and III lines discarded last year, due to high seed coat mottling incidence, will be tested in contract year 1978-79. Tests will also be conducted to determine the incidence of seed transmission in the 14 lines that exhibited no evidence of SMV seed transmission when they were inoculated with other SMV strains.

Appendix II contains a detailed report of work on identification of virus-resistant tropically-adapted soybean germ plasm and identification of soybean germ plasm with low incidence of SMV seed transmission.

Insect Control Through Genetic Improvement. Selective studies, reported in last year's progress report, toward the development of insect resistant genetic material continued and some work was integrated into a breeding program started in 1971 that seeks to incorporate resistant traits of PIs 171.451 and 229.358 into commercial varieties of soybeans. Although these PIs had originally been selected for resistance to the Mexican bean beetle, there is evidence that they also confer resistance to other soybean defoliators such as the bean leaf beetles and velvetbean caterpillars, both serious pests of soybeans in Latin America. Work under this breeding program has been in cooperation with scientists from USDA, UPR/MC, and Purdue University. Screening has been done in Illinois, Maryland, Brasil and Puerto Rico.

Appendix III contains more information on research on development of improved genetic material for use in LDC soybean breeding programs that has been conducted by University of Illinois, Illinois Natural History Survey, and United States Department of Agriculture personnel.

Varietal development and Cooking Quality. The search was continued for varieties of soybeans which become the most tender upon cooking. Twenty-seven varieties of soybeans from the 1976 crop were tested for tenderness after they were cooked by one of four methods. The objective tenderness of each variety for the last three years was compared to its chemical composition and physical characteristics in a search for factors which correlated with the tenderness of cooked whole soybeans.

Data from varieties harvested in 1974 and 1975 were reported in last year's report. These experiments were repeated with the 1976 crop in

order to test consistency from one crop year to the next. Major factors influencing tenderness were soaking and cooking solutions, soaking or not soaking the beans, and differences due to variety.

Composition of soaking and cooking solutions had the greatest effect on objective tenderness of cooked whole soybeans. Use of sodium bicarbonate solutions instead of tap water increased the tenderness of soaked and cooked soybeans by 3.3 fold and cooked but nonsoaked beans by 1.7 fold. Soaking before cooking increased tenderness of beans by 2.8 fold when bicarbonate is used and by 1.4 fold when plain tap water is used. The tenderness of cooked soybeans varied with variety from 8.0 to 34.3 in the case of bicarbonate soaked and cooked beans and from 52 to 96 for nonsoaked and tap water cooked soybeans.

The relative tenderness among varieties varied with soaking and cooking treatment. A given variety was not always more tender than another given variety under all four soaking and cooking conditions. This year three varieties, Cobb, Ransom and Semmes, were among the six most tender varieties in all four treatments.

The tenderness of each variety of cooked whole soybeans was not consistent from one crop year to the next over the last three years. Only Cobb soybeans were among the six most tender varieties in all three years.

Certain characteristics correlated with the tenderness of the cooked whole soybeans, depending on the soaking and cooking treatment used. These characteristics were: a) change in weight after soaking and cooking, b) change in weight after soaking only and c) moisture content.

Details on the results summarized above can be found in Appendix IV.

Objective 2. Improvement of Technologies for Rhizobium Production and Management in Tropical Ecologies

The program of work under this objective began in June, 1977 with employment of Dr. R. Stewart Smith as soil microbiologist. Site selection, personnel recruitment, and planning had been done earlier. The *Rhizobium* microbiologist is located on the Mayaguez campus of the University of Puerto Rico in facilities made available by that institution as part of the interinstitutional collaborative agreement. The research program initiated during this contract year developed rapidly. The major thrust of the research is to better understand some of the factors affecting *Rhizobia* and soybean nodulation in the tropics. Five separate research projects were initiated. Preliminary results of each are summarized below. More complete information is presented in Appendix V.

1. Influence of the rate of soybean emergence on nodulation parameters. Sand bench and first field experiments were completed and statistically analyzed. Significant differences in plant and root dry weight were obtained in the sand bench and first field experiment between nearly every adjacent pair of treatments. Data indicate that the

increasing number of days for a soybean seed to emerge results in a successively smaller plant. Examination of the number of tap root nodules, total nodules and total nodule weight per plant also indicates a significant decrease in these nodulation parameters as the number of days to emerge increases. A significant difference in total nodulation occurs in both experiments when comparing the two most vigorous treatments. There were also significant differences in plant weight between these two treatments in both experiments. The study suggests that a significant variation is introduced into this type of evaluation by sampling plants which vary in seedling vigor. It is recommended, therefore, that only plants of initial uniform growth and vigor be utilized in studies or tests examining rhizobial inoculants and rhizobial nodulation.

2. Number of Rhizobium japonicum necessary to establish satisfactory nodulation in tropical soils. One of the more practical problems concerning inoculation of soybeans in LDC's is to determine the minimum number of Rhizobium japonicum bacteria needed to produce acceptable tap root, total nodulation and to obtain maximum seed yield in the tropics. Also the longevity of R. japonicum in tropical soils under the influence of detrimental environmental factors is an important question to be determined.

   Data from two samplings for nodulation and plant growth parameters have been collected but not statistically analyzed. Seed yield will be obtained later to complete the portion of the study concerned with the number of rhizobia required to obtain satisfactory nodulation.

   Although statistical analysis of the collected nodulation data has not been performed, the raw data permit some general comments. For both harvesting periods the plant and root dry weights were not affected by the rhizobial inoculation rates. It appears that ample soil nitrogen was available to provide sufficient uniform vegetative growth. Seed yield differences will be important in determining the adequate level of nodulation to provide sufficient nitrogen for maximum seed yield under tropical conditions.

   Inoculation levels of R. japonicum were made at different logarithmic increases. The logarithmic increase in the inoculating level of R. japonicum provided an increase in both the number of tap root and total nodules. However, the average nodule dry weight per plant became more steady above the 3.9×10^5 R./cm rate. This is caused by the inverse relationship between the total numbers of nodules and the average dry weight per nodule. It is hoped that significant increases in seed yield will be achieved with nodulation. This will provide a basis for estimating the rate of R. japonicum required on virgin soybean soil in the tropics to provide a satisfactory supply of symbiotically fixed nitrogen to allow for maximum yields.

3. Screening of Rhizobium japonicum strains for growth at elevated temperatures. High soil temperature is a characteristic in many areas of the tropics and subtropics which may be a significant detrimental factor to the establishment of R. japonicum in the seed zone. Preliminary screening of R. japonicum strains for growth on agar spread plates at various temperatures provided several useful trends. When comparing the various incubation temperatures utilized, R. japonicum strains grew most rapidly and profusely when incubated at 30°C. The most significant observation from the first two experiments in this study is that strains of R. japonicum vary in their ability to grow at temperatures above optimum. Preliminary screening of R. japonicum strains at high incubation temperatures indicates there are significant differences among strains. Further research will be conducted to extend the investigation from agar plate growth to host nodulation at high temperatures with the most temperature tolerant R. japonicum strains.

4. Evaluation of alternate inoculant carriers for the tropics. A standard carrier for Rhizobia in inoculant production throughout the world has been finely ground peat. This material has been used for over 40 years and still provides the best suitable material both from the rhizobial bacteria performance and economic standpoints. In the development of inoculant practice and production in LDC's, other methods of inoculating and alternate carriers will have to be developed because of the general lack of appropriate peat sources in the tropics. Not all peat sources are suitable as an inoculant carrier, therefore all potential peat materials must be thoroughly tested in association with Rhizobia bacteria. This study seeks to evaluate the suitability of a chemically treated and nontreated coconut "coir" dust along with a semi-tropical source of muck and compare them to a commercially available peat source from the United States. Preliminary results of the study indicate that water holding capacity for the carriers vary greatly. The treated and untreated coir had greater water holding capacity than either of the organic soil materials tested. This would allow a much larger quantity of rhizobial culture to be incorporated into a given weight of the coir materials. However, further testing must be performed to determine the optimum moisture content in the coir carriers for rhizobial growth and survival.

   Particle size distribution data for the four carriers indicates that the organic soils had a much higher percent particle size, smaller than 170 mesh. The fine particle size is advantageous because of an increased moisture absorbing rate and greater ability to adhere to seed when used as a seed applied inoculant.

   The organic matter content of the coir carriers was much higher than the organic soils. The physical and chemical properties of the coir carrier appears to be satisfactory as a seed applied inoculant. However, rhizobial growth and survival will determine its potential as an inoculant carrier in the tropics.

Carrier evaluations will continue via both agar plate counts and host nodulation examinations until rhizobial counts decrease to a level prohibiting reliable evaluations.

5. Nitrogen fixation screening with Azospirillum lipoferum and eight sorghum hybrid lines. A cooperative project with staff from the Mayaguez Institute of Tropical Agriculture (MITA) was conducted at the USDA Research Station at Isabela, Puerto Rico. The objective of the trial was to screen eight sorghum hybrid lines for effective nitrogen fixation in association with an inoculated strain of Azospirillum lipoferum.

The most probable number estimate for A. lipoferum from root segments shows that both the inoculated and noninoculated plants contained appreciable numbers of this organism. This would indicate that Azospirillum was abundantly associated with sorghum roots even without inoculation and that inoculation with A. lipoferum had no effect on the population of this bacteria associated with the sorghum roots.

In addition to the research studies reported above, a collection of Rhizobium japonicum strains was assembled to which will be added, as received, other strains demonstrating favorable characteristics. Thirty-four strains now in the collection were received from the USDA's Cell Culture and Nitrogen Fixation Laboratory, The Ohio State University, Cornell University and Texas A&M University. These strains were originally isolated from India, Brasil, Japan and several states in the United States.

This collection served as the source of Rhizobium japonicum strains for the high temperature tolerance screening trial and will also be used to provide strains for future strain evaluations such as host strain efficiency evaluations and tolerance in acid Ph soils.

During the next calendar year a study on the influence of weed competition in soybeans on the establishment of Rhizobium nodules will be conducted in cooperation with Dr. Guillermo Riveros at the Isabela Experiment Station. The experiment will have the objectives of investigating the effects of various weed competition levels on nodulation establishment, determining the yield loss resulting from the absence of nodulation by comparing inoculated versus uninoculated plots, and comparing possible yield losses resulting from any decrease in nodulation by comparing yields to a plot receiving nitrogen fertilizer.

Observations were made of nodule damage due to feeding of the bean leaf beetle larvae (Cerotoma). Little research has been conducted to determine the extent of damage by Cerotoma and their influence on nitrogen fixation and possible yield loss. While counting the nodules of a soybean inoculation experiment at the Isabela Substation

the characteristic nodule damage from Cerotoma was observed. In two incidents the larvae was observed protruding from a nodule. The extent of nodule damage from the Cerotoma larvae was 32% of the total nodules and 46% of the plants evaluated having at least one damaged nodule. Intentions are to initiate research in this problem area during the next contract year in cooperation with an entomologist to be hired by the University of Puerto Rico. Cooperation with the INTSOY entomology staff at the Urbana-Champaign campus of the University of Illinois will be encouraged and beneficial.

Appendix V contains the detailed report of work under Objective 2.

Objective 3. Management and Expansion of the Knowledge Base in Soybean Production, Protection, and Utilization

Five basic information systems have been used to expand and make available to cooperating scientists information on soybean production, protection, and utilization. The International Soybean Variety Experiment (ISVEX), Soybean Preliminary Observation Trial (SPOT), and Soybean International Experiment Variety Evaluation (SIEVE) provide a coordinated system of expanding, managing, and disseminating the knowledge of soybean germ plasm. This system was explained in the discussion of Objective 1. Closely allied is the Taxonomic Information Retrieval System (TAXIR) for maintaining the germ plasm data bank. In soybean entomology are the Soybean Insect Research Information Center (SIRIC) and the International Reference Collection of Soybean-associated Arthropods (IRCSA).[1/] The INTSOY Newsletter and INTSOY Publication Series also provide means of disseminating information to soybean workers round the world.

TAXIR

The soybean germ plasm data bank (TAXIR) is a storage bank of information concerning soybeans. Information is obtained from many sources and includes information on germ plasm ranging from named soybean varieties through collections of wild species related to the cultivated soybean. The data are entered and stored in a system that can handle a total of 175 descriptive bits of information for each entry.

Direct INTSOY staff salary support for TAXIR was phased out in 1977-78 as other sources of support for the system were identified. A TAXIR publication "Pedigrees of Soybean Cultivars Released in the United States and Canada" by T. Hymowitz, C. A. Newell, and S. G. Carmer was published as Number 13 in the INTSOY Publication Series.

[1/] Both SIRIC and IRCSA are jointly supported by Contract AID/ta-c-1294 and 211(d) Grant AID/CM/ta-g-73-49 as the strengthening of both systems adds to the institutional response capability of the University of Illinois as well as supporting the research to improve varieties of soybeans for tropical and subtropical conditions.

SIRIC

The Soybean Insect Research Information Center (SIRIC) is a computerized information storage and retrieval system for the worldwide literature of arthropods associated with soybeans. SIRIC is primarily a researcher service oriented unit, operating in close cooperation with the Soybean Entomology Research Team of the Illinois Natural History Survey and the University of Illinois.

The main objectives of the center are periodically reassessed in response to changing information needs of researchers. Currently, SIRIC views its responsibilities as follows:

1. To compile the literature of soybean-related arthropods and to establish a data bank for this literature.

2. To organize a collection of relevant documents using code word descriptors for ready retrieval by means of computerized searches.

3. To help soybean researchers with their information needs.

These objectives were fully addressed during the report period. New procedures for the input operations allow for more efficient and accurate loading of bibliographic data and the magnetic tapes. By December, 1977 SIRIC files contained 16,200 citations representing an increase of approximately 4,000 citations over the previous year.

During the time covered by this report, 122 requests for service were filled in the form of computer printouts, manual compilations, copies of documents, and referral services. Requests outside the scope of SIRIC were routed to the proper institution or specialist. Special care is exercised to see that the supply of document copies are in accordance with the new U.S. copyright law (Title 17 - United States Code) in effect since January 1, 1978.

Fifty-three percent of all requests to SIRIC for information or services came from researchers at the University of Illinois, primarily those associated with INTSOY; the remaining 47 percent were received from individuals and other institutions in the United States and abroad. Key soybean insects are also important pests of corn, alfalfa, and other crops. For this reason SIRIC has been able to answer questions for information coming from researchers working with crops in addition to soybeans.

Bibliographies compiled and published within the framework of SIRIC have an importance that exceeds their value as guides to the literature of selected insect species. Four bibliographies have been published so far on the literature of arthropods associated with soybeans. SIRIC is now working on the production of the fifth bibliography of two *Heliothis* species (*Heliothis* zea and *Heliothis* virescens). These are extremely important agricultural pests on a world scale. Because of their importance, much fundamental research on ecology, physiology, genetics and behavior has been conducted using these species as labora-

tory subjects. The bibliography should have great interest to soybean researchers as well as those interested in pest management in general.

See Appendix VI for the complete report of SIRIC.

IRCSA

The International Reference Collection of Soybean-associated Arthropods (IRCSA) currently houses about 110,000 identified specimens received from 23 soybean producing states in the United States and from 35 foreign countries. The purposes of the collection are four-fold:

1. To survey the soybean-associated arthropods of all soybean producing areas of the world with major emphasis on the phytophagous species and their parasites and predators.

2. To monitor the major pest species for possible changes in distribution.

3. To aid in predicting insect problems in areas initiating soybean production.

4. To provide identification services for soybean researchers and producers.

Major emphasis is placed upon the quality of the identifications of the material in the collection. To assure a high level of authoritativeness in the determinations, almost all material is submitted to outside systematists who are recognized experts in their fields for verification. A cooperative network of about 125 systematists in domestic and foreign academic institutions has been assembled for this purpose.

During the contract report period important and extensive acquisitions have been received from El Salvador, Costa Rica, Panama, Colombia, Ecuador, Nigeria, Sri Lanka, Korea, and the Philippines. During the same period identifications have been provided to soybean workers in Argentina, Brasil, Colombia, Costa Rica, Ecuador, El Salvador, Panama, Peru, Puerto Rico, and Sri Lanka.

At the present time collaborative studies of the fauna of Mexico, Colombia, and Brasil are being made. Additionally, comprehensive studies of two pest complexes, bean leaf beetles and stink bugs, are being conducted. With the collection of extensive materials from the New World, IRCSA now hopes to expand holdings from the Old World. The Old World collection holds material from Ethiopia, Sudan, Uganda, Nigeria, South Africa, Iran, Pakistan, India, Sri Lanka, Thailand, Indonesia, Malaysia, Philippines, Japan, China, Korea and Australis. In an attempt to identify possible new sources of material for the collection a questionnaire was circulated in the fall of 1977. Some 60 responses have been received to date, including 20 from Africa, 5 from Europe

and the Near East, 11 from Asia, and 5 from Australia and Oceania. These will be followed up in 1978-79.

Staff of the Insect Pest Management Studies group are presently editing a book on sampling procedures for soybean arthropods. This book, going to researchers and extension personnel around the world, contains the latest methodology and technology for sampling soybean arthropods, both pests and beneficial species. It will make estimates of population densities more comparable between localities and it will definitely give a good start to entomologists beginning to work in the field of soybean pest management, regardless of their location. Approximately 23 U.S. and foreign specialists are cooperating in the preparation of the book, which should be completed by the end of 1978.

See Appendix VII for the complete report on IRCSA.

INTSOY Newsletter and Publication Series

The INTSOY Publication Series continues to expand. Two titles were published in the current contract year. They were:

1. "Rust of Soybean: The Problem and Research Needs," Report of a Workshop sponsored by the Government of Philippines, the International Soybean Program, INTSOY, The Asian Vegetable Research and Development Center, AVRDC, and the Philippines Council for Agricultural and Resources Research, PCARR. INTSOY Series No. 12.

2. "Pedigrees of Soybean Cultivars Released in the United States and Canada" by T. Hymowitz, C. A. Newell, and S. G. Carmer. INTSOY Series No. 13.

Arrangements were made to reprint INTSOY Series No. 2 "Proceedings of the Workshop on Soybeans for Tropical and Subtropical Conditions," copies of which are in heavy demand and supply of which had been exhausted. In addition, the manuscript for "Whole Soybean Foods for Home and Village Use," is in preparation stages and will be published as No. 14 during the next contract year. This promises to be a significant publication as it addresses the problem of processing and use of soybeans for human food using technologies suitable for home and village levels.

The INTSOY Newsletter, while not intended to be a major vehicle for distribution of detailed knowledge on soybean production, protection and utilization, remains an effective means of bringing such information to the attention of interested readers. The Newsletter, which is distributed free of charge, currently has a mailing list of over 2,100, about two-thirds of whom have overseas addresses.

Objective 4. Improvement of the Knowledge Useful for Disease Control in Soybeans

Disease control is addressed primarily by scientists in plant pathology and entomology. Viral and fungal diseases and virus vector relationships

are the primary areas of concentration. The virologist participated individually or collaboratively in the following nine major activities:

1. Detection of SMV in seeds and seed parts by enzyme-linked immunosorbent assay (ELISA). The purpose of the work was to develop a procedure for accurate and reliable testing of soybean seeds for the presence of SMV that would be quicker, easier, and would require less greenhouse space than the infectivity index method utilizing local lesions on Top Crop beans. The ELISA approach was chosen because, in practice, it is simple, sensitive, and conservative of materials. Since the test uses antisera and other materials and reagents in almost micro amounts it promises to be very inexpensive. ELISA is also sensitive to very small amounts of virus, is easy to do and to read, and requires very little special equipment.

2. Studies on the mechanism of soybean mosaic virus (SMV) seed transmission. Last year's annual report commented on studies on SMV detection in reproductive parts of soybean seeds throughout the reproductive growth of the plant. These studies continued in the 1977-78 contract year and were designed to locate infective virus in mature seed parts and to compare infectivity tests with ELISA as methods to study seed infection by SMV. In the interest of testing whether ELISA could be used to predict the incidence of seed transmission, seed parts were tested both by infectivity and ELISA. The results of those tests imply that SMV seed transmission is the result of embryo infection and ELISA cannot be used on whole seeds to accurately predict the incidence of seed transmission in a seed lot. Dissection of seeds or testing of germinated seedlings should be used if ELISA tests are to be employed in seed certification.

3. Studies on the virulence of seedborne SMV isolates from the USDA Soybean Germ Plasm Collections. SMV is the most widespread soybean virus posing an important threat to soybean production in areas where aphid vectors are plentiful and active. Research on SMV is based on a need to generate information that may be used to control SMV spread in the field. Since the virus is seedborne, attention has been given to reducing the prevalence of seedborne virus in lines and varieties. The use of genetic resistance to infection by SMV has also been studied. While other soybean workers have released varieties reportedly resistant to SMV infection, no one had previously investigated the possibility that various SMV strains differing in virulence might exist. To test this, SMV isolates from a wide range of soybean germ plasm were collected and the virulence of the isolates were tested against six reportedly resistant and two known susceptible soybean varieties.

4. Genetic studies on cowpea mosaic virus. Studies on the genetics of CPMV begun last year were concluded. The objective of the study was to determine if strains of this multi-component, beetle transmitted virus can recombine to form new pathotypes. The results,

which have been published, showed that genetic pseudorecombination can occur. Work on this virus is being concluded because the virus does not appear to spread to soybeans readily even when infected cowpeas are interplanted with soybeans.

5. Studies of the DNA genome of bean golden mosaic virus (BGMV), a whitefly transmitted plant virus. Work on this novel plant virus begun last year has continued. Bean golden mosaic virus is the first whitefly transmitted virus discovered and characterized. The virus contains an unusually small single-stranded DNA genome molecure. The results of these studies have been published; however, several basic questions having to do with how such a small DNA molecule can cause disease and whether the virus is multi-component or not have not yet been resolved and work is therefore continuing.

6. Preparation and testing of the specific antiserum to BGMV. BGMV was purified and used to immunize a six-pound New Zealand white rabbit. Sera were obtained from the rabbit at various times although the virus used for injection was highly purified antibodies specific for phytoferritin were also present in the BGMV antiserum. Since BGMV infected plants produce large amounts of phytoferritin and since phytoferritin levels in healthy plants are very low, the presence of phytoferritin in immunogens or antibodies specific for phytoferritin in virus antisera must be reckoned with in the interpretation of serological tests with this virus. The BGMV antiserum has been used to study the sedimentation components associated with BGMV and has been distributed to cooperators in Nigeria, India, Israel, and Brasil for testing.

7. Ultrastructure of an infection by BGMV. A study has been made of the time course and ultrastructural aspects of BGMV infection in bean cells using the electron microscope. The work showed that BGMV infects the nuclei of bean cells associated with phloem. Dramatic ultrastructural alterations occur in infected nuclei that are unlike any caused by previously known plant viruses. These observations have been used to diagnose a disease from a weed plant common in Costa Rica as caused by a whitefly-transmitted virus that infects soybean in tropical America.

8. Attempts to purify and characterize whitefly-transmitted viruses from soybeans. Unsuccessful attempts to purify soybean infected whitefly-transmitted viruses were made early in 1977 in cooperation with Dr. Julio Bird, University of Puerto Rico, and in late 1977 in cooperation with Dr. J. Vetten, International Institute of Tropical Agriculture in Nigeria. A cooperative investigation is now underway with Dr. S.P.S. Beniwal to see if electron microscopy can be used to diagnost soybeans infected with mung bean yellow mosaic viruses from India.

9. Attempt to purify the agent causing lima bean golden mosaic in Nigeria. In collaboration with Dr. J. Vetten of IITA an unsuccessful attempt was made to purify the lima bean golden mosaic agent. This is suspected to be a virus related to BGMV. Serological tests are now underway at IITA to check this possibility more directly.

Detailed results of soybean virus research are in Appendix II.

Fungal and Bacterial Diseases

The major thrust of the research on fungal and bacterial diseases is to better understand the effects of various microorganisms on soybean seeds and seed quality and development of control methods. The fungal and bacterial pathologist concentrated on an assessment of factors that influence disease, diseased seeds and seed quality, and control of soybean diseases. In assessing factors that influence disease, a number of studies were completed on the association and effect of *Bacillus subtilis* on soybean seed germination *in vitro* and emergence in soil. In one study surface disinfected soybeans were placed on moist cellulose pads and subjected to a temperature series of five degree centigrade increments from 15° through 55°C. As temperature increased the incidence of *B. subtilis* increased and germination decreased. Seeds previously stored at different temperatures were placed on cellulose pads at 35°C and potato dextrose agar (PDA) at 25°C at two-week intervals for eight weeks. There was a resulting decrease in germination and concomitant increase in occurrence of *B. subtilis* as storage temperatures increased.

In another study 26 surface disinfested soybean seed lots of the cultivars, Bragg, Dare, Hill, Lee 68 and Amsoy 71 were bioassayed for *B. subtilis*. The seed lots were obtained from five states and occurrence of *B. subtilis* among all seed lots did not differ among states.

In a third test Amsoy 71 soybean seeds were treated with streptomycin sulfate at 5, 10, 15, 25 or 35 milograms per 20 grams of seeds. After varying the numbers of hours of exposure at 25°C, washed cotyledons were bioassayed. Inhibition zones of *B. subtilis* were noted and found to increase in size with an increase in rate and time. Thin layer chromotography confirmed streptomycin activity in tissues of treated seeds. *B. subtilis* was consistently isolated from dead and decayed seeds. Streptomycin treated seeds produced significantly lower currents of decayed seeds and significantly higher germination *in vitro* than nontreated seeds.

A continuing study concentrates on the epidemiology of *Phomopsis sojae*, causal fungus of soybean pod and stem blight disease. Harvested soybean pods containing mature seeds at three stages of senescence were inoculated with *Phomopsis spp*. Pods were either wounded or nonwounded and placed in a moist chamber at room temperature. Visible lesions developed after two to four days, the majority developing at the base of trichomes

with penetration occurring between epidermal cells. Pods of all cultivars at all three stages of senescence were invaded by Phomopsis spp. Seed infection was delayed in green pods with reduced severity in frequency compared to that of yellow and brown pods.

The quality of diseased seeds was further studied by measuring the compositional changes and reduction of oil quality in soybean seeds infected with Phomopsis sojae. Three seedlots of Wells soybeans with greater than 20% seedborne Phomopsis spp. were bulked and seed was separated on the presence or absence of visual symptoms of Phomopsis spp. infection. Seeds exhibiting symptoms had 12% germination compared to 86% for symptomless seeds. Seed weight, volume and density were significantly lower in seedlots with visible symptoms. Soybean meal was measured for protein and oil percentage. Oil and protein content was significantly higher for meal from seed with symptom expression. Meal from seed exhibiting symptoms was gray with a rancid odor. Various tests of oil of seed exhibiting symptoms showed that oil quality was reduced.

Control of soybean disease studies concentrated on seed treatment and fungicide sprays. One study indicated the seed treatments could affect seed quality by influencing the fungi associated with seed at the end of the growing season. Competition between the fungal microflora is altered with seed treatment and affects the type of fungi isolated. In another study the soybean variety Amsoy 71 was treated with aqueous polyethylene solutions, soaked, dried, and planted. Germination was either less than or not significantly different from that of nontreated seed. Field emergence of seeds treated with penicillin G plus thiram dust was significantly higher than that of nontreated seeds and seeds treated with thiram alone.

Reports were made on two studies about various seed treatments effects on emergence and yield under field conditions. Seedlots were either treated with polyethylene glycol incorporated penicillin G or left as control. Emergence in yield from seeds treated with PEG plus penicillin G were not significantly greater than those from nontreated seeds, which suggests that control of bacteria on soybean seeds without fungal control may have little effect on germination. In the second study, seed samples were selected from soybean lots harvested from either Benlate sprayed (good quality seeds) or nonsprayed (poor quality) plants and were treated with various methods and planted. The mean percent emergence was significantly higher from the nontreated, good quality seeds than from any other treatment. Seeds treated with DPX-115B at two ounces and Benlate-T at four ounces produced a significantly higher yield than nontreated, poor quality seeds and were not significantly different from nontreated, good quality seed.

In a test of fungicide sprays, Wells soybeans were field planted and sprayed with one, two, or three applications of nine fungicides before flowering, during early flowering, early-podding, mid-pod, late-pod, or very late-pod stages. Plants were threshed and a total yield of 1000 seed weight recorded. Seeds were germinated on a PDA with germination being considered when the radical was 1.5 times the length of the cotyledons. Germination was higher and the occurrence of Phomopsis spp.

and total fungi were lower when fungicides were applied at mid-pod or early-pod plus mid-pod. Differences between fungicide treatments were more apparent among seeds from late harvest than first harvest with respect to yield. Seed weight, germination in vitro, total fungi, Alternaria spp. and recovery of Phomopsis spp.

See Appendix VIII for a detailed report of research on soybean fungal and bacterial diseases.

Virus Vector Studies

Soybean Mosaic Virus (SMV) occurs wherever soybeans are grown and is the most common and most important virus infecting soybeans. Because the amount of SMV field spread differs between growing regions, it is important to isolate factors responsible for the spread. SMV is transmitted from generation to generation through the seed (vertical transmission) and in the field by various species of aphids in a nonpersistent manner (horizontal transmission). Two factors stand out as being extremely important in the field spread of SMV: percentage of the planted seed that is SMV infected and flight timing and abundance of vector species. INTSOY studies have indicated that there are no important alternate host plants of SMV in central Illinois and that alternate plants probably play a minimal role as primary inoculum sources in the Midwest. Little is known about this aspect in other areas as yet. Aphids do not colonize soybeans in the U.S. and very rarely do they colonize soybeans in the western hemisphere. Thus, the soybean itself if not a factor in the population dynamics of field vectors, at least in the U.S., and probably not in the western hemisphere. Some species of aphids do colonize soybeans in Africa and Asia and this added factor must be understood in those areas.

Because SMV is seed transmitted, it is endemic in seedlots everywhere. In the North Central United States infected seed from one growing season provides the primary inoculum source during the next. The percent of infected seed can, to a large extent, determine the potential for field spread. While the incidence of SMV infected seed in certified seedlots produced in Illinois is well below .01%, it may be much greater elsewhere in the world.

A second cooperative study between virology and entomology staff focused on the transmission of cowpea mosaic virus from cowpeas to cowpeas and soybeans and the field spread of CPMV-PR. Beetles were allowed to feed on a single, healthy cowpea seedling for two days immediately before use in transmission experiments. Beetles were also allowed to feed on seedlings inoculated with CPMV-PR. Twenty seedlings each of cowpeas and soybeans were exposed to beetles previously fed on infected leaves and 10 each to beetles previously fed on healthy leaves. None of the field collected beetles were viruliferous since no cowpea plants exposed to individual beetles showed any virus-like symptoms. All cowpea plants and three out of 20 soybean plants inoculated by beetles fed on infected leaves became infected. No transmission was obtained from plants exposed to beetles previously fed on healthy leaves.

Two similar experiments were conducted at Isabela, Puerto Rico to check field spread of CPMV-PR. Cowpeas were mechanically inoculated with CPMV-PR when plants were at the primary leaf stage. Two weeks after planting all noninoculated cowpea plants were removed and replaced with soybeans. The spread of the virus was determined by observing the number of soybean plants infected with CPMV-PR which was confirmed by serological tests. Many soybean plants with virus-like symptoms were found during the first observations, but results from serology tests indicated that these plants were not infected with CPMV-PR. The injury in soybeans caused by beetle feeding was about 5 to 10% consumption of the leaf area at the canopy top. Again, no CPMV-PR infected soybean plant was found.

Appendix II and Appendix III contain more detailed reports of virus vector studies.

Objective 5. Development of Model Insect, Weed and Disease Control Management Systems Which Can Be Adapted or Modified for Specific Environments

The entomology group gave leadership to the development of pest management systems through two studies. One study considered the bionomics and spacial distribution of soybean associated thrips. Two species of thrips were studied. *Sericothrips variabilis* and *Frankliniella tritici* were found to colonize soybean plants in Illinois, Kentucky, and Missouri. Horizontal distributions within fields and among plants did not differ significantly. However, both species were vertically stratified within the soybean canopy. Both species occurred in soybean fields throughout the growing season. However, peak population levels appeared earlier, population densities were generally higher, and rates of population buildup and decline were more pronounced in the southern locations.

Although damage thresholds have not been established for these thrips species, there are some guidelines that could help determine sampling procedures:

1. There are two critical sites on soybean plants for these colonizing species, terminal buds for *F. tritici* and the fifth from uppermost trifoliolates for *S. variabilis* immatures.

2. Distribution patterns ranged from uniform to aggregated with no detectable relationships between pattern and plant growth stage or thrips density.

3. Border rows have an unknown effect on thrips population.

4. *S. variabilis* appears to cause greatest damage during the vegetative stages of plant growth.

A study conducted for the past three years on field activity of *Orius insidiosus* was monitored during the report period. Data has not been

completely analyzed, but results from wind directed impact trapping indicate that this species tends to fly into the wind, and with a similar but stationery impact trap, prevailing wind had little effect on flight direction. Sex ratios tended to change through the season from more males in the spring to slightly more females in the fall. The 30th or 31st week of the year seemed to be the changeover point. Other aspects of Orius flight activity are being analyzed.

Appendix III contains a more detailed report of this research.

Objective 6. Development of Improved Seed Storage Technology

Last year's annual report contained the results of a study conducted by the Departments of Agronomy and Agricultural Engineering at UIUC and the Department of Agricultural Engineering, UPR/MC, that was developed to study practical and inexpensive methods for storing seed under tropical conditions. The maintenance of soybean seed quality during storage in hot, humid environments typical of LDC's was recognized as a limiting factor in soybean production. High quality seed is required to obtain stands for profitable soybean production. As local seed production becomes possible, a storage technology suitable for the environment and scale of operations becomes essential. The study showed that soybean seed does not store well as compared to other legumes. The major environmental factors influencing seed deterioration were temperature and moisture.

During the 1977-78 contract year some follow-up work to the study was accomplished. Using Woodworth seed grown in Puerto Rico at the Isabela substation, 432 200g. samples were prepared. The storage conditions were designed to correspond to the resources available to farmers for seed storage in the tropics. Five factors were studied; storage conditions, moisture levels, container types, storage periods, and seed treatment. Seeds were planted in the sand bed at Isabela. All five factors studied were statistically significant in the maintenance of emergence in sand. The most significant single factor was initial moisture content. The rapid loss of germination in storage in the tropics under the conditions of this experiment was directly related to percentage of moisture level of the seed in storage at the time seeds were in storage. The best containers for storage are those that maintain a low initial moisture content. Seeds treated with thiram did not germinate any better than the untreated seeds. Insulation also had no effect of practical significance. Parallel sealed can storage tests in Urbana at 25°C (the mean ambient temperature at Puerto Rico) gave germination results similar to those obtained at Isabela. The seed multiplied in Puerto Rico stored less well than the parent seed from Illinois. Details of this experiment may be found in Appendix IX. A paper reporting on this research has been prepared for presentation at the 1978 Summer Meeting of the American Society of Agricultural Engineers to be held at Utah State University, Logan, Utah, June 27-30, 1978.

D. Ancillary Activities

INTSOY staff have participated in a number of activities funded by noncontract sources but supportive of the objectives of the contract.

Since 1975 INTSOY has sponsored two short-term applied soybean training courses."Soybean Processing for Food Uses," a six-week course, is taught in the spring and "Technical and Economic Aspects of Soybean Production," a course lasting about four months, is taught during the late spring and summer growing season. The courses were developed in cooperation with the U.S. Department of Agriculture's Office of International Training, the U.S. Agency for International Development, the Food and Agriculture Organization and other donor groups. Eighty-five persons from 50 countries had received training in the two courses prior to 1978.

In early spring of 1977 after a year of planning and preparation, the Asia/Oceania Soybean Rust Workshop convened in Manila, The Philippines. Joining INTSOY in sponsoring and supporting the Workshop was the Government of The Philippines, The Asian Vegetable Research and Development Center (AVRDC) and the Philippine Council for Agriculture and Resources Research (PCARR). INTSOY, through the aegis of this research contract, was able to provide for the travel and transportation expenses of nine participants from five countries of the region. The papers presented at the Workshop were published as Number 12 in the INTSOY Series that has been referenced earlier in the report.

Research contract staff continue to participate in a number of areas consistent with the overall goals of the contract. Advisory service has been provided under Agency supported task orders, e.g., support to Faculty of Agronomy, University of Panama, in development of applied research programs in soybean production and protection. International organizations such as the Food and Agriculture Organization of the United Nations have requested and received assistance from INTSOY staff on identification missions, technical consultations, and country programs. Considerable consultation between INTSOY staff members and scientists of international agricultural research centers continues.

Workshops, seminars, and conferences have been enriched by the contributions of INTSOY research staff. Collaborative programs under various memoranda of understanding have also benefitted from the participation of the contract staff. These ancillary activities are supportive of both the total INTSOY program and of the research contract under report. Participation in these activities enriches and broadens the capacities of the research staff and are an important part of the total program.

E. Administration, Staff and Budget

The program continues to be administered by a Director and Assistant Director located at UIUC and an Associate Director located at UPR/MC. Staff of the two universities have worked continuously and in close harmony to integrate the activities of the research contract and

complementary agency supported projects and to the overall programs of the respective campuses. The Directorate staff receives policy guidance from an executive committee comprised of heads of departments involved in the program and representatives from the Experiment Station, the Cooperative Extension Service, International Agricultural Programs, and the Office of International Programs and Studies.

At the end of the report period the Directorate and professional group numbered 7.25 full-time equivalent staff. They were assisted by 14.0 full-time equivalent support personnel. The significant contribution of the various support personnel to the overall success and progress during project goals is gratefully acknowledged. A listing of all personnel who have served during the life of the contract is presented on pages 26, 27, and 28.

Funds for project operations in the second year of the contract were adequate and during the year funds for the balance of the contract were made available. Summary of expenditures for the first two years of the project and an estimate of requirements to the end of the contract are given below.

Program Budget

Line Item	Actual Exp. 4/1/76-3/31/77	Actual Exp. 4/1/77-3/31/78	Total Exp. 4/1/76-3/31/78	Est. Exp. 4/1/78-3/31/79	Total Est. Budget
1. Salaries	$214,225	$274,648	$488,873	$429,065	$917,938
A. Professional	(103,250)	(146,857)	(250,107)	(215,465)	(465,572)
B. Support	(110,975)	(127,791)	(238,766)	(213,600)	(551,366)
2. Fringe	21,740	27,298	49,038	40,385	89,423
3. Indirect Cost	141,390	179,133	320,523	246,350	566,873
4. Travel & Transportation	42,280	38,349	80,629	47,000	127,629
5. Other Direct Costs	31,205	50,897	82,102	97,800	179,902
6. Equipment & Supplies	28,875	62,415	91,290	112,800	204,090
	$479,715	$632,740	$1,112,455	$973,400	$2,085,855

INTSOY Project Staff

April 1, 1976 - March 31, 1978

Name	Rank/Title	Department	FTE
A. Professional Staff			
Abrams, Raul	Assoc. Director	INTSOY Administration	.25
Bouseman, J. K.	Asst. Entomologist	Ag. Entomology (from 8/21/77)	.5
Dunker, R. E.	Asst. Agronomist	Agronomy (to 10/20/76)	1.0
Ferrier, L. K.	Asst. Professor	Food Science (to 10/5/77)	.75
Goodman, R. M.	Asst. Professor	Plant Pathology	.75
Hill, H. J.	Asst. Agronomist	Agronomy (from 12/1/76)	1.0
Hittle, C. N.	Professor	Agronomy (4/1/76 to 7/9/76)	.25
Irwin, M. E.	Asst. Professor	Ag. Entomology	1.0
Judy, W. H.	Assoc. Professor	Agronomy (from 6/1/77)	.75
McCowen, T. A.	Asst. Director	INTSOY Administration	.25
Minor, H. C.	Asst. Professor	Agronomy (to 4/17/78)	.75
Nelson, A. I.	Professor	Food Science (from 8/21/77)	.25
Rodda, E. D.	Professor	Ag. Engineering (to 8/20/77)	.25
Sinclair, J. B.	Professor	Plant Pathology	.25
Smith, R. Stewart	Asst. Professor	Agronomy (from 6/13/77)	1.0

Name	Rank/Title	Department	FTE
A. Professional Staff (con't.)			
Thompson, W. N.	Director	INTSOY Administration	.25
Wei, L. S.	Professor	Food Science (from 10/21/77)	.25
Whigham, D. K.	Asst. Professor	Agronomy (to 4/11/77)	.75
B. Support Staff			
Allison, Elizabeth (Schaefer)	Res. Assistant	Ag. Entomology (from 6/7/76)	1.0
Anderson, Debora	Res. Assistant	Agronomy (from 5/21/77)	1.0
Appleman, J. D.	Res. Assistant	Food Science (to 11/23/76)	1.0
Baer, K. D.	Res. Assistant	Food Science	1.0
Bowers, G. R., Jr.	Res. Assistant	Plant Pathology (from 5/21/76)	.50
Brinkman, G. S.	Res. Assistant	Plant Pathology (from 5/21/76)	.50
Burnsmier, Helen	Clerk III	Agronomy	1.0
Cunningham, Patricia	Clerk-Typist III	INTSOY Administration	1.0
Eckenbeck, Susan L.	Res. Assistant	Agronomy (from 7/21/76-10/31/77)	1.0
Endsley, Margaret R.	Clerk-Typist III	Agronomy (to 9/27/77)	1.0
Foor, S. R.	Res. Assistant	Plant Pathology (from 4/1/77 to 7/20/77)	.50
Halbert, Susan E.	Res. Assistant	Ag. Entomology (from 5/21/76)	.50
Kanthamani, S.	Res. Assistant	Food Science (to 11/23/76)	.25

Name	Rank/Title	Department	FTE
B. Support Staff (con't.)			
Kogan, Jenny	Res. Assistant	Ag. Entomology (from 1/21/77)	.25
McClary, Richard D.	Res. Assistant	Plant Pathology (from 9/21/77)	1.0
McCune, T. D.	Res. Assistant	Food Science (to 8/20/76)	1.0
Newell, Christine A.	Res. Associate	Agronomy (to 8/20/77)	1.0
Primmer, R. R.	Assistant I	Ag. Engineering (to 4/29/77)	.50
Rokke, Douglas L.	Staff Assistant	Ag. Engineering (from 8/8/77)	.25
Schneider, Barbara L.	Res. Assistant	Agronomy (from 2/1/78)	1.0
Shock, Teresa L.	Asst. Plant Pathologist	Plant Pathology (from 9/7/76)	1.0
Taeger, Deanna	Secretary	INTSOY Administration	1.0
Thongmeearkom, P.	Res. Assistant	Plant Pathology	.50
Toews, Vicki L.	Clerk-Typist III	Plant Pathology	.50
Tucker, Margaret E.	Clerk-Typist III	Food Science	.50
Weger, Laura	Clerk-Typist III	Agronomy (from 10/5/77)	1.0
Yeh, C. C.	Res. Assistant	Plant Pathology (from 1/21/78)	.50

APPENDIX I

Development of Improved Genetic Materials and Production Traits

William H. Judy, Associate Professor of Agronomy and
H. J. Hill, Assistant Agronomist

I. SOYBEAN VARIETY DEVELOPMENT

The major objectives of the soybean variety development program include selection for high, stable yield and high protein per unit of land area. In order to accomplish this, the breeding and testing program has concentrated on selection of varieties with a suitable photoperiod response, resistance to diseases and insects which limit yield and quality, and wide agronomic adaptability to tropical and subtropical environments.

In order to accomplish these objectives, INTSOY has posted a plant breeder at UPR/MC for the purpose of evaluating the tropical and subtropical germplasm and making crosses between high yielding temperate and tropically adapted germplasm.[1/] The varieties developed in the Puerto Rico program are evaluated in the Soybean Preliminary Observation Trial (SPOT) which was carried out at six locations in 1976 and at eight locations in 1977. This program has now begun to pay off as there are six varieties in the 1978 ISVEX trials which were selected through this breeding program.

The preliminary thrust in the soybean variety development work is through the International Soybean Variety Evaluation Experiments (ISVEX). The ISVEX trial provides an opportunity for testing the adaptation of soybean varieties under a wide range of environmental conditions in comparison with introduced and locally available cultivars in the country where the trials are conducted. This comprehensive variety testing program depends upon the voluntary collaboration of cooperators. The participation has grown from 33 countries and 90 locations in the first year of research contract AID/CM/ta-c-73-19 to over 70 countries and 186 locations during 1977. Table 1 shows the distribution of cooperators who completed the 1976 ISVEX and returned agronomic data and seed samples for oil and protein analysis.

Over the years, the kinds of varieties included in this trial have varied considerably. As a result of evaluation by the trial coordinator and of suggestions by cooperators, the varieties were grouped into early, medium and late maturing trials. This procedure was followed for the fourth, fifth, and sixth ISVEX during 1976, 1977, and 1978. The cultivars included during these three years are listed

---

1/ A.I.D. 211(d) Grant AID/CM/ta-g-49 is the primary support for the plant breeder and details of that work are in reports of that grant. Work reported here is complementary to the 211(d) grant work as was planned at the inception of Contract AID/CM/ta-c-73-10 and the 211(d) Grant.

in Table 3. In 1977, there were 26 varieties from maturity group 0 to IX. For the first time, varieties developed in the INTSOY soybean breeding program at Puerto Rico were included in ISVEX. These varieties include CH-3, UFV-1, SJ-2, Hardee LS, Orba, and IAC-2. In addition, INTSOY cooperators in Colombia supplied Tunisia and Caribe. All eight are adapted to tropical and subtropical conditions.

The trial coordinator supplies the seed for all experiments except the local variety, and provides inoculum, a standard set of instructions, and data collection sheets. The cooperator in the country provides the land, labor, fertilizer and management necessary for the experiment. Instructions for management and data collection are standardized and sent to each cooperator. General information returned by the cooperator included details such as latitude, elevation and soil conditions, plus date of planting and harvesting, amount of moisture from rainfall or irrigation, fertilizer use, local varieties tested, and observations on diseases and insects. The data reported for each plot by the cooperators included yield, nodulation, days to flowering, days to maturity, plant height at maturity, estimates of lodging and shattering, and seed quality. Samples of each of the varieties were also returned to INTSOY for protein and oil content analysis. Data from the trials are then interpreted according to ecological zones which are categorized according to latitude and altitude.

All data have been received for both the third ISVEX (1975) and fourth ISVEX (1976) and are being interpreted for publication. The distribution of ISVEX among environmental zones is shown in Table 4. During 1975, 75% of the trials were carried out between 20°N and 20°S in tropical and subtropical geographical areas; in 1976, 62% of the trials were located in these areas.

The Soybean Preliminary Observation Trial (SPOT) was organized in 1975 to provide a means for evaluation of the environmental response of newly developed cultivars at a limited number of sites. The cultivars included in SPOT during 1976, 1977, and 1978 are listed in Table 5. These cultivars have been obtained from selections in the INTSOY breeding program in Puerto Rico and from soybean breeding programs of cooperators in Asia and South America. There were six new entries in 1977 and seven new entries in 1978. The number of locations has been increased from eight in 1977 to 18 in 1978 in order to obtain a more precise evaluation of new varieties in different environments. Five entries from the 1976 and 1977 SPOT trials were selected for includion in the 1978 ISVEX.

At the time of this report, INTSOY has received requests from 81 countries for 211 ISVEX trials to be conducted in 1978. To date, 80 trials have been forwarded to cooperators.

While conducting the ISVEX and SPOT trials it became evident that there were a number of soybean breeding programs which were developing improved and adapted varieties of soybeans. Therefore, the soybean variety development group decided to organize a system to take advantage of this promising germplasm pool. A new trial was

organized to begin in 1978 which is being called the Soybean International Experiment Variety Evaluation (SIEVE) trial. A total of 66 plant breeders were contacted with the request that they contribute up to three cultivars developed to the F-6 or later stages. There were 48 cultivars contributed from cooperators in 15 different countries as shown in Table 6.

This SIEVE collection is to be evaluated at 0°, 18°, and 30° latitude. In addition to yield, observations will be made on all agronomic and pest-resistance characteristics of these varieties. Selections from this SIEVE trial and from the Puerto Rico breeding program will be entered in the SPOT trial. It is expected that approximately 50 to 100 entries can be handled in the SIEVE trial and 20 to 40 varieties in the SPOT trial. Selections will be made from the SPOT trial for inclusion in the ISVEX trial which will continue with 16 varieties. The cultivars in the SPOT trial will be increased in order to have sufficient seed for those selected to go into the ISVEX trial the following year. When this system is fully operative, it is estimated that a variety can move from the breeder to the farmer in a minimum of four years and that all active breeding programs in the world could contribute to the tropical and subtropical genetic improvement program.

Up to now, the top yields in tropical and subtropical locations have been obtained with cultivars developed in temperate environments. These temperate cultivars do not produce ideal plant types when grown in the tropics but the breeding program at Puerto Rico has demonstrated that, by crossing temperate cultivars with exotic tropical and subtropical material, varieties can be developed which produce a more ideal plant type and higher yields. However, now INTSOY has developed the complete varietal development system SIEVE-SPOT-ISVEX which provides a system for thorough evaluation and rapid introduction of the best-adapted varieties for all tropical and subtropical soybean breeders.

A survey was developed and distributed among cooperators in November, 1976. The replies are tabulated in Table 7. Most respondents believed there was a good opportunity for an increase in soybean acreage in their country and that the beans, if produced, would be used for human food. There was strong support for the germplasm, training, and communication functions of INTSOY. There was also an expressed need for technical assistance from INTSOY for improving production and utilization.

II. INTSOY SUPPORT FOR SCIENTISTS IN ALLIED AND RELATED DISCIPLINES

Two varieties of soybeans were sent to an INTSOY cooperator at the University of Liberia, College of Agriculture, near Monrovia, for the purpose of carrying out soil fertility experiments on the University farm. The soil is acidic and low in available phosphorus. There is a high rainfall pattern which affects the fertility status of the soil and satisfactory growth of soybeans. It is expected that research carried out at the University will be of value in Liberia as well as in comparable high rainfall areas of the tropics.

Cooperators were provided inoculum and soybean varieties for the purposes of identifying the best carriers of Rhizobia and improved methods for applying the inoculum to the seed or to the soil. Inoculum was sent to Senegal, Ethiopia, and Indonesia. Cultivars of nodulating and non-nodulating isolines were sent to Ghana. High-yielding adapted varieties of soybeans were supplied to French Antilles and to the NIFTAL Project at Paia, Hawaii. The importance of the N-fixing ability of soybeans to the crop itself and to other subsequent crops grown in the same field has been increasingly recognized as one of its major benefits.

Varieties of soybeans have been sent to Bolivia, Brasil, Colombia, Peru, El Salvador, France, Honduras, Nigeria, and Upper Volta in order to supply soybean breeders and agronomists with improved cultivars for crossing and selection. The collection of cultivars sent to the cooperator supplements those varieties which had already been sent through ISVEX and SPOT trials. After conducting INTSOY variety trials, cooperators are able to more precisely identify the characteristics of cultivars which were required for specific purposes within each country. Assistance has been given to cooperators who have need for cultivars with reduced photosensitivity or tolerance for saline or acidic soil conditions.

A small lot of all ISVEX and SPOT entries were sent to the Plant Quarantine Section of EAAFRO in Nairobi, Kenya for clearance and placement in cold storage. These 45 varieties will then be available to soybean improvement programs in Kenya, Uganda, and Tanzania.

Seed for drought tolerance trials were sent to ICARDA at Aleppo and to the Ministry of Agriculture at Douma near Damascus, Syria. The Douma station was also sent a nematode resistant variety trial.

A small lot of all ISVEX varieties were sent to Rodale Press, an organic gardening and vegetable research organization in Pennsylvania, in order to obtain an evaluation of their sprouting qualities.

Aluminum and manganese toxicity are associated with low pH soils and are typical of high rainfall tropical soils. Low rainfall tropical and subtropical soils, on the other hand, are typically saline. Seed for two trials were sent to the University of Hawaii for evaluation in a liming and manganese study. A set of varieties was sent to Saudi Arabia for evaluation for salt tolerance on irrigated land.

III. RESEARCH CARRIED OUT BY RESEARCH ASSISTANTS

A research project by a research assistant, a University of Illinois graduate student, was undertaken to identify those stages of development at which various soybean plant densities undergo the specific effects of competition. A second purpose was to identify the stages of plant development when particular plant populations start to lose their ability to compensate for reductions in plant stand.

Varieties Hark and Williams were evaluated at four plant populations which were thinned at half the original population at three vegetative and three reproductive stages of development. More than 30 plant characteristics were studied in reference to competition among plants and in compensation for reduction in plant population. It is expected that the results of this research will improve knowledge about management of the crop and selection of specific genotypes for higher, more stable yield. Results will be used in devising strategies to cope with stand reduction which might result from various causes such as pest or other environmental effects.

Another research assistant has begun greenhouse research on the effects of low pH and aluminum toxicity on soybeans. Soils with low pH are typical of high rainfall areas in the tropics and subtropics. Six varieties have been evaluated in the greenhouse to determine which are more tolerant to low pH and aluminum. Experiments will then be carried out in the field in Puerto Rico in order to evaluate the effect of a high-aluminum soil on plant growth and development and to examine several methods for amelioration of this particular problem. All advanced lines of soybeans from the plant breeding program in Puerto Rico will be screened for aluminum tolerance in the greenhouse using high-aluminum soils.

IV. COOPERATION WITH OTHER INTERNATIONAL ORGANIZATIONS

In 1976, INTSOY carried out soybean variety trials in cooperation with the International Institute for Tropical Agriculture (IITA) in Ibadan, Nigeria. The trial was composed of 16 varieties. Eight varieties were supplied by IITA and eight by INTSOY. The half-sets were sent directly to the cooperator from each international organization and then were planted at the same time by the cooperator. During 1976, 79 cooperative INTSOY/IITA trials were carried out in African countries. This system was continued in 1977 when 65 cooperative INTSOY/IITA trials were carried out in tropical and subtropical areas.

The ISVEX trials for North Africa and Middle Eastern countries were sent in cooperation with the FAO Regional Field Food Crops Project which has headquarters in Cairo, Egypt and field staff in Sudan, Iraq, and Syria. The soybean agronomist located in Tehran, Iran identified the locations for the ISVEX trials throughout the Middle East and North Africa.

The French tropical food research organization Institut de Recherches Agronomiques Tropicales (IRAT) cooperated with INTSOY by conducting ISVEX trials at a number of locations in West Africa.

Low phosphorus availability is the factor most frequently limiting plant growth after nitrogen. There are sources of rock phosphate of varying quality throughout the world. A project was initiated in Upper Volta to evaluate a local source of rock phosphate. This project is in cooperation with the West German AID organization and the International Fertilizer Development Center in Alabama. The INTSOY agronomist provided the soybean seed varieties, Davis and Forrest, and suggested a research design for the three year experiment.

V. DISCUSSION OF RESULTS FROM ISVEX AND SPOT

During 1975, cooperators in 90 countries conducted 259 ISVEX trials. Of these, cooperators in 64 countries returned useable data for 143 trials. These data are being analyzed and interpreted for publication in the summer of 1978.

During 1976, cooperators in 84 countries conducted 292 ISVEX trials. Of these, cooperators in 65 countries returned data from 138 sites. There were 114 sites with data suitable for combining within environmental zones. The distribution of trial sets is shown in Table 8. The results for yield of grain and days to maturity for the five highest-yielding varieties within environmental zones are reported in Tables 9, 10, and 11.

The data from joint INTSOY/IITA trials conducted in 1976 and which were suitable for combining within the environmental zone are reported in Table 12.

A. Summary of 1975 ISVEX

For ISVEX trials conducted in tropical and subtropical areas between 30°N and 30°S, yield of grain decreased strongly with increase in altitude and slightly with increase in latitude. Days to flowering increased with an increase in both altitude and latitude. However, the time required for maturity increased more with increasing altitude than with increasing latitude. Altitude had little effect on plant height. Plants grew taller at higher latitudes with little effect on lodging. Neither lodging nor shattering were serious problems at most sites. Seed weight decreased with increasing latitude but altitude had no consistent effect. Surprisingly, seed quality decreased with altitude but was not affected as trials moved closer to the equator. Oil percentage increased with latitude but protein content did not exhibit trends.

B. Summary of 1976 ISVEX

The 1976 ISVEX trial consisted of a pool of 27 cultivars which were variously apportioned among eight different sets. Each set was designed for specific environmental conditions (see Table 4 for description of environmental zones and Table 8 for distribution of trial sets among environmental zones). Of the group of 27 varieties evaluated in 1976, nine cultivars were common to the past three ISVEX, seven were new, and four were common among all eight trial sets.

The high grain yield achieved in the experimental plots with good management in the ISVEX trials indicates that soybeans do have

production potential in many new areas of the world. For example, the variety Pickett 71 yielded 6,535 kilograms per hectare (kg/ha) in an experiment conducted in Jordan. Bossier yielded 6,126 kg/ha in Peru. There were five locations where the yields exceeded 5,000 kg/ha. These included Iran, where Wells yielded 5,492 kg/ha, Sri Lanka, where Forrest yielded 5,376 kg/ha, Tahiti, where Davis yielded 5,288 kg/ha, Bolivia, where the variety Bragg yielded 5,153 kg/ha, and Egypt, where Calland yielded 5,022 kg/ha. There were two sites in Asia where the mean yield for all varieties was was 4,700 kilos per hectare; four sites in South America averaged 4,371 kg/ha; three sites in Africa averaged 4,363 kg/ha; and three sites in the Middle East averaged 4,363 kg/ha.

In the more tropical environmental zones I, II, and IV, Davis and Forrest were among the five highest-yielding varieties (Table 9) as well as in the environmental zones III and V-VIII (Table 10) which are more subtropical in climate. Other varieties such as Improved Pelican, Bossier, and Bragg consistently yielded well in these environmental zones. The five highest-yielding varieties in more temperate climates such as zones IX and X are shown in Table 11.

Combined analyses were made across sites within the environmental zones when five or more sites were available in a zone.

Environmental Zone I, 0°-10° latitude, 0-500m altitude: At these 15 sites, Davis was reported as the highest yielding cultivar at 2525 kg/ha (Table 9). This was significantly higher than Forrest, Improved Pelican, Bragg and Williams. The average yield for Zone I was 2271 kg/ha. Jupiter was the latest maturing cultivar with 115 days to harvest; Williams was earliest at 88 days to maturity. The mean days to maturity for Zone I was 95 days. Days to maturity was positive and significantly correlated with yield. The tallest variety was Improved Pelican at 74 cm and the shortest was Davis at 33 cm. Plant height was also positive and significantly correlated with yield. Other agronomic characteristics which had a positive significant correlation with grain yield included number of plants harvested, pods per plant, and 100 seed weight.

Environmental Zone IV, 11°-20° latitude, 0-500m altitude: Davis was the highest yielding cultivar with 2466 kg/ha (Table 9). However, the yield of Davis was not significantly different from Calland, Forrest, Cobb or Bragg. Woodworth, a group III cultivar, matured earliest at 84 days; Improved Pelican matured latest at 102 days. Because of this later maturity, Improved Pelican had a plant height of 86cm as compared to the mean of 48cm. Bossier was the shortest variety at 36cm. Nodule number and nodule weight had a positive but small significant correlation with yield. Maturity, plants harvested, pods per plant, and 100 seed weight

were positive and significantly correlated with yield, although the correlation coefficients were not as strong as in the combined analysis for Zone I.

Environmental Zone III, 0°-10° latitude, above 1000m altitude: The mean yield for all varieties at the six sites was 1535 kg/ha (Table 10). This was 500 kg/ha lower than the mean for all varieties in Zone I. Hill was the highest yielding cultivar with 1990 kg/ha, but the five top yielding varieties did not differ significantly from one another. Improved Pelican was the latest maturing cultivar at 150 days, and also the tallest at 70 cm. Agronomic parameters such as days to flower, days to maturity, plant height, number of pods per plant were positive and significantly correlated with yield.

Environmental Zone VI, 11°-20° latitude, above 1000m altitude: The five sites contributing to the combined analysis for Zone VI reported a mean yield of 2809 kg/ha for all varieties (Table 10). Davis was the highest yielding cultivar with 3207 kg/ha, but there was no significant difference among the top five varieties. Davis took the most days to flower, 43 days, and to mature, 109 days, of the top five yielding cultivars. Davis also grew tallest at 66cm compared to the mean of 53cm. Calland was the earliest and the shortest variety of the top five varieties with 97 days to maturity and a plant height of 45cm. Days to maturity and days to flower were weakly correlated with yield. However, nodule number, nodule weight, plants harvested per plot, pods per plant, and 100 seed weight were positive and significantly correlated with yield.

Environmental Zone VII, 21°-30° latitude, 0-500m altitude: Davis was the highest yielding cultivar with 2371 kg/ha but there was no significant difference among the top five yielding varieties (Table 10). Ransom was the latest variety to mature at 117 days, but only Forrest, which matured at 106 days, was significantly different from other varieties. There was no significant difference in plant height among the top five varieties. Mean days to maturity in this zone was 106 days and the mean plant height was 51cm. Days to flower, days to maturity, nodule number, nodule weight, plant height, plants harvested, pods per plant, and 100 seed weight were all positive and significantly correlated with yield.

Environmental Zone X, 31°-40° latitude, 0-500m altitude: This environmental zone is the transition between more tropical and more temperate regions. Because of shorter day length, the U.S. varieties developed in the upper midwest yielded more than those developed in the southern areas. Williams, Group III, averaged 3,324 kg/ha over the eight sites, but there was no significant difference among the top five varieties (Table 11). Calland matured latest at 122 days. Only Woodworth matured significantly earlier than Calland. Williams was the tallest plant at 91cm

compared to the mean of 85cm for the top five varieties. Days to flower and days to maturity were not positively correlated with yield. Nodule number, plant height, plants harvested per plot, pods per plant, and 100 seed weight were all positive and significantly correlated with yield.

Summary of tropical and subtropical locations: Between 30°N and 30°S latitudes, the days required before flowering and days to maturity increased with increase in latitude and altitude. Plant height increased with increasing latitude. Plant height and amount of lodged plants were not highly correlated. Neither lodging nor shattering were serious problems at most sites, and there was no consistent relationship of shattering and environmental zone. Weight per 100 seed (seed weight) decreased with increasing latitude, but increased with increasing altitude. Pod number, another parameter of yield, was found to be inversely correlated with 100 seed weight. Pod number increased with increasing latitude, but decreased with increasing altitude. Oil percent increased with latitude, but protein percent was not related to environmental factors.

Joint INTSOY/IITA trials, Environmental Zone I, 0°-10°latitude, 0-500m altitude: These trials consisted of eight IITA varieties and eight INTSOY varieties selected for adaptation to tropical regions. Results of the six combined sites are reported in Table 12. Davis was the highest yielding cultivar with 2138 kg/ha. There was no significant difference in yield among entries. The mean grain yield of 1887 kg/ha for all varieties was lower than the mean for the group of sites in Zone I, reported in Table 9, however, the mean yield for the IITA and INTSOY group of entries was comparable. As a group, the IITA entries matured later and grew taller. Entry TGx 13-3-2644 matured latest at 107 days and Williams earliest at 83 days.

C. Summary of 1976 SPOT

The soybean grain yield and days to flowering are reported in Tables 13 and 14, respectively, for the six sites which conducted the SPOT during 1976.

The SPOT locations ranged from 2° to 29° latitude and from 8m to 1506m altitude. The five highest-yielding varieties (other than the standard varieties Jupiter and Bossier) included Hardee LS, SJ-1, CH-3, SJ-2, and Santa Rosa. Because of superior agronomic characteristics and wider adaptability, three varieties Hardee LS, CH-3 and SJ-2 were selected for inclusion in the 1978 ISVEX trial.

Days to flowering and to maturity decreased as latitude and altitude increased. Both days to flower and to maturity are correlated with plant height. Plant height is correlated with lodging and pods per plant. However, neither pods per plant nor 100 seed weight is highly correlated with grain yield.

VI. PROGRESS REPORT ON THE FIFTH ISVEX (1977)

A total of 186 ISVEX trials was dispatched to 84 countries during 1977. The group entries included 50 cultivars plus one blend. The range in maturity groups was from 00 to IX. These entries were divided into early, medium and late maturing groups and distributed among environmental zones. Cultivars Williams, Mitchell, Calland, and Cobb were common to each trial. The blend designated B-1 was composed of Davis (VI), Bossier (VII), and Cobb (VIII). Blends give a wider range of maturity and favorable plant characteristics in one planting and have had some success in the United States.

The INTSOY/IITA trial was composed of eight INTSOY and eight IITA varieties. Williams and Cobb were the common varieties in the ISVEX and INTSOY/IITA trials. These trials were distributed to cooperators between 20°N and 20°S latitudes.

So far, data have been returned from 42 locations which conducted ISVEX.

VII. PROGRESS REPORT ON THE SIXTH ISVEX (1978)

Three sets of cultivars are currently being distributed in 1978. The cooperative trials with IITA have been discontinued after two years of testing. As of the date of this report, 211 trials had been requested from 81 countries. Eighty trials have been dispatched and others will be sent.

Trial sets were developed to include varieties more adapted to environmental conditions. Set A is designed for tropical conditions and includes entries in maturity groups VI-IX. Set B, for subtropical zones, includes maturity groups IV-VIII. Set C, for latitudes greater than 30°, contains maturity groups 00-IV. Cultivars which consistently have shown high yield potential in past years, such as Davis, Forrest, Improved Pelican, Jupiter, Bossier, and Williams, have been included in the 1978 ISVEX. Williams (III) is included in all three sets as a standard check.

Several new cultivars have been entered in ISVEX. Tropical set A has been completely revised. After undergoing two years of preliminary testing in SPOT, the seed for selected cultivars developed in tropical areas was increased in Puerto Rico. These new entries include CH-3 (Taiwan), UFV-1 (Brasil), Orba (Indonesia), and Hardee LS (INTSOY, Puerto Rico). Three cultivars, developed in South America, have been well evaluated and were also added in 1978. These include Tunia and Caribe, both from Colombia and IAC-2 from Brasil. This is the first year that the majority of cultivars (11 out of 16) in the tropical set are from maturity groups VIII and IX. Newly developed U.S. entries include Franklin and Union, cultivars developed in the midwest with resistance to all three races of cyst nematode and two races of phytophthora root rot. Crawford, developed from a Williams-Columbus cross, is resistant to shattering and has better seed quality. Elf is the first semi-dwarf determinate group III variety ever developed with

excellent resistance to lodging and a high response to good management. Gasoy 17, developed in Georgia, and James, developed in Delaware, also have promise for potential adaptation to subtropical areas. Several early maturity cultivars have been entered for the first time in the temperate trials. Among these are Harcor and Evans.

The data requested from each trial have also been changed in 1978. Because of lack of response from cooperators, the nodule rating system has been simplified. Abundance and activity can now be recorded with a numerical rating rather than actually counting and weighing all the nodules. Pod height (lowest pod height from ground level) has been added as a parameter because of the potential loss if pods are set too close to the ground surface.

Lack of seed quality limits soybean production under tropical conditions. Little is known at present about how ISVEX varieties differ in seed quality. Therefore, information on seed quality has been requested through observation and germination of harvested seed.

The instruction booklet has been improved. Additions include both a summary page and narrative for crop management and data collection. A listing of INTSOY publications and other publications on soybean production has been included. Addresses of specialists in production problems and pest management have been added to aid the cooperator in solving individual problems. A list of selected characteristics of all varieties was included in the instruction booklet in order to aid cooperators in identifying varieties that may be most adapted to their areas. This information includes maturity group; insect, disease, and nematode resistance; special morphological traits; and country of origin.

Table 1 : Locations which completed the fourth ISVEX (1976) and sites which returned samples for oil and protein analysis

Region	Country	Location	Protein & Oil samples
AFRICA	Algeria	Khemis-Miliana	x
		Forme Molca	
		Parakou	x
	Botswana	Gaberones	
		Mahalapye	
	Burundi	Buhoro	
		Sems/IMBO	x
	Cameroon	Dschang	
		Santchou	
	Central African Empire	Bossangoa	
	Congo	Lekana	x
	Egypt	Bahteem	x
		Giza	x
		Seds	x
	Ethiopia	Awassa	x
		Dedessa	x
		Jimma	x
		Leku	x
	Gabon	Ntoum	x
		Ntoum	x
	Ghana	Kumasi	x
		Legon Farm	
	Ivory Coast	Abidjan	
		Dekokaha	
		Odienne	
		Sirasso	
	Lesotho	Maseru	x
	Mali	Koulikoro	x
	Niger	Maradi	x
	Nigeria	Ibadan	x
	Rhodesia	Salisbury	x
	Somalia	Afgoi	x
	Sudan	Wau	x

BEST AVAILABLE COPY

Table 1 (cont'd): Locations which completed the fourth ISVEX (1976) and sites which returned samples for oil and protein analysis

Region	Country	Location	Protein & oil samples
AFRICA (cont'd)	Swaziland	Big Bend	
		Malkerns	x
		Mangcongo	x
	Tanzania	Ilonga	
		Zanzibar	
	Togo	Amoutchou	x
		Barkoissi	x
		Davie	x
		Kitangbao	x
	Uganda	Kampala	x
	Upper Volta	Bobo-Dioulasso	
	Zaire	Kisanga	x
	Zambia	Kabwe	
		Magoye	
		Magoye	x
		Magoye	x
		Magoye	
		Mufulira	x
ASIA	Bangladesh	Joydevpur	
		Kashimpur	
		Mymensingh	x
		Pabna	x
	India	Jabalpur	
		Pantnagar	x
	Indonesia	Malang	x
		Medan	x
	Nepal	Khairanitar Farm	x
		Khumaltar	
	Pakistan	Islamabad	
		Kotdiji	
		Kotdiji	
		Lahore	
		Lahore	
		Mingora	
		Mirwah	
		Swat	
		Tandojam	
		Tandojam	
		Umerkot	

BEST AVAILABLE COPY

Table 1 (cont'd): Locations which completed the fourth ISVEX (1976) and site which returned samples for oil and protein analysis

Region	Country	Location	Protein & oil samples
ASIA (cont'd)	Philippines	Los Banos	x
	Sri Lanka	Alutharama	x
		Alutharama	
		Angunukolapalessa	
		Bandarawela	
		Bandarawela	
		Bandarawela	
		Gannoruwa	x
		Gannoruwa	
		Gannoruwa	
		Kilinochchi	
		Kilinochchi	
		Mahailluppallama	x
		Mahailluppallama	
		Okkampitiya	
		Puttalam	
		Thirunelvely	
	Thailand	Khon Kaen	
		Saraburi	
		Sukothai	
		Sukothai	
		Surat Thani	x
		Suwan Farm	
EUROPE	Hungary	Godollo	x
		Szarvas	x
	Italy	Sassari, Sardinia	
		Ussana, Sardinia	
	Poland	Radzikow	x
	Portugal	Porto	x
	Spain	Seville	x
	Yugoslavia	Novi Sad	x
MESO-AMERICA	Bahamas	San Andros	x
	Dominican Republic	San Cristobal	x
	Jamaica	Caymanas	x
	Mexico	Apatzingan	x
		Apatzingan	x
		Tepalcatepec	

BEST AVAILABLE COPY

Table 1 (cont'd): Locations which completed the fourth ISVEX (1976) and sites which returned samples for oil and protein analysis

Region	Country	Location	Protein & Oil samples
MESO-AMERICA (cont'd)	Nicaragua	Managua	
		Posoltega	
	Puerto Rico	Isabela	x
	Trinidad & Tobago	Port-of-Spain	x
MIDDLE EAST	Iran	Karaj	
		Rezaiyeh	x
		Safiabad	
	Iraq	Abu-Ghraib	x
	Israel	Bet-Dagan	x
		Bet-Dagan	x
	Jordan	Deir Alla	
		Wadi Dhuleil	
	Saudi Arabia	Wadi Jizan	x
NORTH AMERICA	United States	Urbana, Illinois	x
OCEANIA	New Caledonia	Bourail	x
	New Hebrides	Port Vila	x
	Tahiti	Papeete	x
	United States	Kapaa, Hawaii	x
		Kapaa, Hawaii	x
		Kauai, Hawaii	x
SOUTH AMERICA	Argentina	Parana	
	Bolivia	Santa Cruz	x
		Santa Cruz	
	Brazil	Janauba	x
		Manaus	
		Manaus	
		Manaus	
	Chile	La Platina	x
	Colombia	Palmira	x
	Ecuador	Boliche	x
		Pallatanga	x
		Portoviejo	
		Pichilingue	x
		Quito	x

BEST AVAILABLE COPY

Table 1 (cont'd): Locations which completed the fourth ISVEX (1976) and sites which returned samples for oil and protein analysis

Region	Country	Location	Protein & Oil samples
SOUTH AMERICA (cont'd)	Paraguay	Caacupe	x
		Capitan-Miranda	
	Peru	Baqua	
		La Vina	
		Lima	
	Uruguay	Tacuarembo	
		Treinta y Tres	

Table 2: List of cooperators participating in the fifth International Soybean Variety Evaluation Experiment (1977)

Region	Country	Name	Address
AFRICA	Algeria	Officer-in-charge	Station Regionale I.D.C.I. Khemis-Miliana (El-Asnam) ALGERIA
	Benin	R. Vanbercie	I.R.A.T. B. P. 422 Cotonou Republique Populaire du BENIN
	Botswana	Dr. D. E. Gollifer	Agricultural Research Station P.O. Box 0033 Gaberones, BOTSWANA
	Cameroon	Mr. J. Praquin	IRAF B.P. 44 Dschang, CAMEROON
	Central African Republic	Mr. Emilein LeFort	Director Project FAO Recherche Agronomique PNUB B. P. 872 Banqui, CENTRAL AFRICAN REPUBLIC
	Congo	Ing. Ivetic Obrad	PDR PROJECT ILO 68-507 P.O. Box 465 Brazzaville PEOPLE'S REPUBLIC OF CONGO
	Egypt	Mr. Addas Hassan Shuwailiya	Alexandria University Faculty of Agriculture Agronomy Department Alexandria, EGYPT
		Dr. Ali Abdel-Aziz, Head	Grain Legume Research Section Field Crops Research Institute Agricultural Research Centre Giza, EGYPT
	Ethiopia	Dr. Alemu Mengistu	Agricultural Experiment Station P.O. Box 32 Debre Zeit, ETHIOPIA

Table 2(Con'd): List of cooperators participating in the fifth International Soybean Variety Evaluation Experiment (1977)

Region	Country	Name	Address
AFRICA (cont'd)	Ethiopia	Mr. Gebre Mariam Shekour	Jimma Research Station P.O. Box 192 Jimma, ETHIOPIA
		Dr. Abdurahman Ali	Awassa Research Station P.O. Box 6 Awassa Sidamo, ETHIOPIA
	Gabon	Mr. J. Van Amerongen	Project FAO GAB 75/003 "CIAM" B.P. 2183 Libreville, GABON
	Gambia	Mr. D. J. Moles	Upland Crop Specialist Rural Development Project Ministry of Agriculture and Natural Resources Private Bag Banjul, THE GAMBIA
	Ghana	Yaw Baafi Nimoh	Grains Development Board P.O. Box 4000 Kumasi, GHANA
		Mr. Hector Mercer-Quarshie	Crops Research Institute P.O. Box 3785 Kumasi, GHANA
		Dr. Bob Dadson	Department of Crop Science Faculty of Agriculture University of Ghana Legon, GHANA
		Dr. Andrew Aryeetey	Agr. Res. Station P.O. Box 9 Kpong, GHANA
	Ivory Coast	Dr. A. D. Assa	Ministry of Agriculture B.P. 4322 Abidjan, IVORY COAST
	Liberia	Mr. D. McCourtie	Project Manager College of Agriculture and Forestry University of Liberia Monrovia, LIBERIA
		Mr. James Kokro	Central Agricultural Expt. Station Ministry of Agriculture Monrovia, LIBERIA

Table 2 (Cont'd): List of cooperators participating in the fifth International Soybean Variety Evaluation Experiment (1977)

Region	Country	Name	Address
AFRICA (cont'd)	Liberia	Mr. Lasana Kromah	College of Agriculture and Forestry University of Liberia Monrovia, LIBERIA
		Mr. Al-Haji Henries	Central Agricultural Expt. Sta. Suakoko, LIBERIA
	Mauritius	Dr. A. L. Owadally	Divisional Scientific Officer Government of Mauritius Ministry of Agriculture and Natural Resources Reduit, MAURITIUS
	Morocco	Dr. Mohamed Abdouh Yacoubi	Institut Agronomique Hassan II B.P. 704 Agdai Rabat, MOROCCO
	Niger	Mr. O. Sidibe	Centre National de Recherches Agronomiques de Tarnan B.P. 240 Mardi, NIGER
	Nigeria	Mr. E. U. Edem	National Cereals Research Institute Uyo Research Station PMB 1032 Uyo, Cross River State NIGERIA
	Rhodesia	Dr. J. R. Tattersfield	Head Crop Breeding Institute P.O. Box 8100 Causeway Salisbury, RHODESIA
	Rwanda	G. Delepierre	Chef du Groupe des Plantes Vivrieres de l'ISAR ISAR Institut des Sciences Agronomiques du Rwanda Station de Rubona B.P. 138 Butare REPUBLIQUE RWANDAISE
	Senegal	Ton That Trink	Research Coordinator OMVS FAO B.P. 154 Dakar, SENEGAL

Table 2 (Cont'd): List of cooperators participating in the fifth International Soybean Variety Evaluation Experiment (1977)

Region	Country	Name	Address
AFRICA (cont'd)	Somalia	Mr. William F. Lyon	Entomologist FAO Project SOM/72/014 Mogadiscio, SOMALIA % UNDP, P.O. Box 20 Grand Central Station New York, NY 10017 USA
		Mr. A. A. Mohammed	Director of Agricultural Research Institute Ministry of Agriculture Mogadiscio, SOMALIA
	Sudan	Mr. David Hopkinson	Agronomist FAO/UNDP Land Development Project P.O. Box 913 Khartoum, SUDAN
	Swaziland	Mrs. Janet Cumberland	Crop Agronomist Malkerns Research Station P.O. Box 4 Malkerns, SWAZILAND
	Tanzania	Dr. Paul C. Duffield	% USAID P.O. Box 9130 Dar es Salaam TANZANIA
		Mr. Alan Carpenter	FAO/UNDP Ministry of Agriculture and Lands P.O. Box 159 Zanzibar, TANZANIA
	Togo	Mr. J. Marquette	Le Chef de la Mission IRAT au Togo B.P. 1163 Lome, TOGO
		Mr. Koffi Kpandja	Direction de la Recherche Agronomique s/c Direction de L'Agriculture B.P. 341 Lome, TOGO
	Uganda	Mr. C. K. Bulungu	Department of Crop Science Makerere University P.O. Box 7062 Kampala, UGANDA

Table 2 (Cont'd): List of cooperators participating in the fifth International Soybean Variety Evaluation Experiment (1977)

Region	Country	Name	Address
AFRICA (cont'd)	Upper Volta	Mr. O. Russell	Le Directeur IRHO/HV Secteur Haute-Volta B.P. 21 Koudougou UPPER VOLTA
		Dr. C. I. Korteweg	Food and Agriculture Organization of the United Nations Centre d'Experimentation du Riz et des Cultures Irriguees B.P. 130 bis Bobo-Dioulasso UPPER VOLTA
		Mr. Joseph Kabore	Directeur des Services Agricoles B.P. 7028 Ouabadongou, UPPER VOLTA
	Zaire	Mr. Miaswekama Nkusu	INERA - Mulungu Bukavu, ZAIRE
		Mr. Edward Charles	SEDA Service du Developpement Agricole B.P. 1 Tshikapa REPUBLIQUE DU ZAIRE
		Mr. Ron Monroe	Methodist Mission % Doug Crowder B.P. 4750 Kinshasa 2, ZAIRE
		Mr. Thomas G. Hart	CIMMYT Team Leader Programme National Mais Department de l'Agriculture Lumbumbashi, ZAIRE
	Zambia	Mr. F. Javaheri	Ministry of Rural Development Department of Agriculture P.O. Box 11 Magoye, ZAMBIA
ASIA	Bangladesh	Dr. Peter R. Hobbs	Associate Agronomist The Ford Foundation P.O. Box 98, Ramna Dacca 2, BANGLADESH

Table 2 (Cont'd): List of cooperators participating in the fifth International Soybean Variety Evaluation Experiment (1977)

Region	Country	Name	Address
ASIA (cont'd)	Bangladesh	Dr. A. Jalil Miah	Head, Plant Genetics Division Institute of Nuclear Agriculture Bangladesh Agricultural University Campus Mymensingh, BANGLADESH
	Burma	Dr. E. W. Bolle-Jones	Project Manager FAO/BUR/72/003 % UNDP, Post Box 650 Rangoon, BURMA
	India	Dr. S. Selvaraj	Asst. Crop Specialist (Pulses) K. K. Agri. Experiment Institute Kudumiamalai Tamil Nadu, INDIA
		Dr. G. Shivashankar	Prof. of Agric. Botany College of Agriculture Hebal Bangalore, 560024 Karnataka, INDIA
	Indonesia	Ir. Soenjoto Djojodiridjo	Department of Agronomy University of Gadjah Mada Jogjakarta, INDONESIA
		Director	Lembaga Pnsat Penelititan Pertanian Jalan Merdeka No. 99 Bogor, INDONESIA
	Korea	Keun Young Park	Chief, Upland Crop Cultural Section Crop Experiment Station Officer of Rural Development Suweon, KOREA
	Malaysia	Mr. Mohamed Shah bin Kadir	Managing Director Soya Industries P.O. Box Pudu 6035 Kuala Lumpur, MALAYSIA
		Dr. N. G. Thai Tsiung	Department of Agronomy Miri Sarawak, MALAYSIA

Table 2 (Cont'd): List of cooperators participating in the fifth International Soybean Variety Evaluation Experiment (1977)

Region	Country	Name	Address
ASIA (cont'd)	Nepal	M. P. Bharati	Agronomy Division Agronomy Experimental Farm Khumaltar Kathmandu GPU 404 NEPAL
	Pakistan	Mr. A. H. Chaudhry	Oilseeds Botanist Agric. Res. Inst. Tandojam, PAKISTAN
		Mr. Sayid Badshah	Economic Botanist Agricultural Research Institute Taimib Peshawar PAKISTAN
		Dr. M. J. Tahir	Deputy Director of Research (Crops) Agricultural Research Council L-13 Almackaz F - 7/2 Islamabad, PAKISTAN
		Mr. Robert Troedson	Agronomist, Agricultural Project Technical Services Association 23-2 Race Course Road Lahore 3 - PAKISTAN
		Mr. Somabad A. Khan	Oilseeds Botanist Punjab Agricultural Res. Inst. Lyallpur, PAKISTAN
	Philippines	Conrado R. Bartolome	Institute of Plant Breeding University of Philippines at Los Banos College, Laguna, PHILIPPINES 3720
		Mr. Benjamin M. Legaspi	Bureau of Plant Industry Economic Garden Los Banos, Laguna THE PHILIPPINES
	Sri Lanka	Mr. H. M. E. Herath	Central Agricultural Res. Institute Gannoruwa Peradeniya SRI LANKA (CEYLON)
		Dr. Carl N. Hittle	Central Agricultural Experiment Sta. Gannoruwa Peradeniya SRI LANKA (CEYLON)

Table 2 (Cont'd): List of cooperators participating in the fifth International Soybean Variety Evaluation Experiment (1977)

Region	Country	Name	Address
ASIA (cont'd)	Sri Lanka	Dr. N. Vignaiajah	Agricultural Research Station Maha Illuppallama SRI LANKA (CEYLON)
	Taiwan	Mr. S. Shanmugasundaram	Res. Assoc. (Breeding) The Asian Vegetable Research and Development Center P.O. Box 42 Shanhua, Tainan, 741 TAIWAN, REPUBLIC OF CHINA
	Thailand	Dr. Paisan Laosuwan	Faculty of Agriculture Khon Kaen University Khon Kaen, THAILAND
		Dr. Arwooth NaLampang	Department of Agriculture Leader of Oil Crop Project Ministry of Agriculture Bangkhen, Bongkok 9 THAILAND
		Dr. Dumrong Tiyawalee	Plant Science Department Faculty of Agriculture Chiang Mai University Chiang Mai, THAILAND
		Aree Waranyuwat	Research Agronomist Northeast Agricultural Center Tha Phra Khon Kaen, THAILAND
		Dr. Prasarn Yingchol	Department of Agronomy Kasetsart University Bangkok 9, THAILAND
EUROPE	Portugal	Mr. Abilio Silva	Agronomist Instituto Nacional de Investigacao Agraria Quinta do Marques Oeiras, PORTUGAL
		Director	Estacio Agraria Ponta Delgada S. Miguel - Azores PORTUGAL

Table 2 (Cont'd): List of cooperators participating in the fifth International Soybean Variety Evaluation Experiment (1977)

Region	Country	Name	Address
EUROPE (cont'd)	Czechoslovakia	Ing. Teodor Sinsky, CSC.	Vyskumny Ustav Rastlinnej Vyroby, Bratislavska Cesta 2696 92168 Piestany, CZECHOSLOVAKIA
	Italy	Prof. Guiseppe Rivoira	Instituto di Agronomia Generale e Coltuazioni Erbacee Universita di Sassari Via E. De Nicola Cod. Post. 07100 Sassari, ITALY
		Dr. D. Bagnara	Centro Studi Nucleari Casaccia 00060 S. Mariadi Galeria Rome, ITALY
	Poland	Prof. Dr. Jerzy Szyrmer	Instytut Hodowli I Aklimatyzacji Roslin Radzikow 05-870 Blonie K/Warszawy POLAND
MESO-AMERICA	Belize	Dr. J. P. Cal	Agronomist Department of Agriculture Ministry of Agriculture & Lands Belmopan, BELIZE
	Guatemala	Director	Instituto de Ciencia y Tecnologia Galeria Espana, 5° Piso 7 Ave. 11-59, Zona 0 Guatemala City, GUATEMALA
	Honduras	Director	Estacion Experimental de Guaymas Direccion Agricola Regional No. 3 San Pedro Sula, HONDURAS C.A.
	Mexico	Dr. Guillermo H. Bravo	Geneticist Food Legumes Program Comision Ejectiva Para el Desarrollo Agricola y Ganadero del Estado de Mexico Plaza Fray Andres de Castro Portales Edificios "A" y "B" Toluca, MEXICO

Table 2(Cont'd): List of cooperators participating in the fifth International Soybean Variety Evaluation Experiment (1977)

Region	Country	Name	Address
MIDDLE EAST	Iran	Dr. L. H. Camacho	UNDP Building 12 KH Bandar Pahlavi Off Takhte Jamshid Tehran, IRAN
		Dr. J. Carapetian	College of Agriculture and Animal Husbandry P.O. Box 32 Rezaiyeh, IRAN
		Dr. G. Noor Mohammadi	Department of Agronomy College of Agriculture Jundi Shapur University Golestan, Ahvaz IRAN
		Dean	College of Agriculture Karaj, Iran
	Saudi Arabia	Mr. Ziad Adham	Acting Director General of Agri. Research and Dev. Dept. Ministry of Agri. & Water Riyadh, SAUDI ARABIA
		Dr. Hsieh Sang Yan	Chinese Agricultural Technical Mission P.O. Box 143 Hofuf Al-Hassa, SAUDI ARABIA
	Syria	Eng. Ahmad Kabalan	Minister of Agriculture Ministry of Agriculture Damascus, SYRIA
OCEANIA	New Caledonia	Monsieur le Chef du Service de l'Agriculture	B.P. 43 Noumea, NEW CALEDONIA
	Australia	Giaeme Robertson	Department of Agriculture Kunumara Western Australia AUSTRALIA
	Fiji	Mr. R. Viner	Research Officer, Dry Zone Department of Agriculture Legalega Research Station P.O. Box 86 Nadi Airport, FIJI

Table 2 (Cont'd): List of cooperators participating in the fifth International Soybean Variety Evaluation Experiment (1977)

Region	Country	Name	Address
OCEANIA (cont'd)	Tahiti	Mr. Jean-Louis Reboul	Service de l'Economie Rurale B.P. 100 Papeete Polynesie Francaise, TAHITI
SOUTH AMERICA	Argentina	Nora Mancuso	Secretaria De Estado de Agricultura y Ganaderia De La Nacion INTA - Estacion Experimental Regional Agropecuaria Pergamino Casilla De Correo No 31-2700 Pergamino PCIA. BS. AS. ARGENTINA
		Ing. Agr. Raul Vicentini	INTA - Estacion Experimental Agropecuaria Casilla de Correo No. 128 3100 - Parana - Entre Rios ARGENTINA
		Wilhelm Reupke	Instituto Nacional de Tecnologia Agropecuaria Av. Corrientes 320 330 Posadas Misiones, ARGENTINA
	Bolivia	Richard J. Peters	Agricultural Officer USAID Bolivia APO New York 09867 P. A. L.
		Ing. Hebert Zurita O.	Enc. Oleaginosas y Fibrotextiles Estacion Experimental Casilla 247 Santa Cruz, BOLIVIA
	Brazil	Dr. Howard L. Cabe	IPB - Comircio De Sementes LIDA Avenida Euzebio Matoso 891° - And CEP 01047 Sao Paulo, BRAZIL
		Mr. Carmine Rosito	Centro de Experimentaacao e Pesquisas-Fecotrigo Caixa Postal, 10 98.100 - Cruz Alta - RS BRAZIL

Table 2 (Cont'd): List of cooperators participating in the fifth International Soybean Variety Evaluation Experiment (1977)

Region	Country	Name	Address
SOUTH AMERICA (cont'd)	Brazil	Chris Suebert	Convenio UPR/EPA MIG Rua amazonas 115-5° Andra Belo Horizante Minas Gerais, BRAZIL
		Dr. Fazil Rahman	INPA Caixa Postal 478 - 69.000 Manaus Amazonas, BRAZIL
	Chile	Dr. Juan E. Lira	Director of Research Faculty of Agronomy Universidad Catolica de Chile Santiago, CHILE
		Dr. P. C. Parodi	Universidad Catolica de Chile Facultad Catolica de Chile Departamento de Fitotecia Casilla 114-D Santiago, CHILE
	Colombia	Ing. Gilberto Bastidas R.	Director of Nacional Programa Leguminosas de Grano y Oleaginosa Anuales I.C.A., Palmira, COLOMBIA
	Ecuador	Ing. Eduardo Calero H.	Head Research 2 Oilseed Program INIAP (Instituto Nacional De Investigaciones Agropecuarios) Estacion Experimental Boliche Apartado No. 7069 Guayaquil, ECUADOR
	Guyana	Herman Adams	Agricultural Officer (Soybeans) Ministry of National Development & Agriculture Central Agricultural Station Mon Repos, East Coast, GUYANA
	French Guiana	Monsieur le Chef de la Mission	IRAT B.P. 60 97301 Cayenne Cedex GUYANE FRANCAISE

Table 2 (Cont'd): List of cooperators participating in the fifth International Soybean Variety Evaluation Experiment (1977)

Region	Country	Name	Address
SOUTH AMERICA (cont'd)	Paraguay	Ing. Robert Casaccia	% Ministerio de Agricultura y Ganaderia Instituto Agronomico Nacional Presidente Franco 472 Asuncion, PARAGUAY
	Peru	Ing. Hugo Soplin V.	Universidad Nacional Agraria la Molina Department de Fitotecnia Apartado 456 Lima, PERU
		Rodolfo Vargas S.	Coordinator Nacional Soya Covenio con AID % Ing. Jose Rodriguez Acevedo USAID Lima, PERU (ID) Department of State Washington, DC 20520
		Mr. Edgardo S. Vilcapoma	Professor de Oleaginosas Universidad Nacional Agraria de la Selva Apartado 156 Tingo Maria, PERU
	Surinam	Ir. T. Van Der Sar	P.O.B. 1914 Paramaribo SURINAM
	Uruguay	Officer-in-charge	Est. Exp. De l'Este Av. Brasil 139 Treinta Y Tres URUGUAY
		Ing. Luis Amendola	Proyecto Suelos y Cultivos Estacion Experimental del Norte Gral. Flores 390 Tacuarembo, URUGUAY
	Venezuela	Dr. Luis Marcano C.	President Fundacion Servico Para El Agricultor Edificio Cavendas, Piso 8, Oficiana 806 Av. Francisco de Miranda Apartado 2224 Caracas, VENEZUELA

Table 3 : List of cultivars included in ISVEX during the years 1976, 1977 and 1978.

	1976		1977		1978	
	Cultivar	Mat. group	Cultivar	Mat. group	Cultivar	Mat. Group
1.	Jupiter	IX	Jupiter	IX	Jupiter	IX
2.	Bossier	VII	Bossier	VII	Bossier	VII
3.	Imp. Pelican	VIII	Imp. Pelican	VIII	Imp. Pelican	VIII
4.	Williams	III	Williams	III	Williams	III
5.	Ransom	VII	Ransom	VII	Ransom	VII
6.	Cobb	VIII	Cobb	VIII	Cobb	VIII
7.	Forrest	V	Forrest	V	Forrest	V
8.	Davis	VI	Davis	VI	Davis	VI
9.	Calland	III	Calland	III	Calland	III
10.	Bragg	VII	Bragg	VII	Bragg	VII
11.	Columbus	IV	Columbus	IV	Columbus	IV
12.	Cutler 71	IV			Cutler 71	IV
13.			Mitchell	IV	Mitchell	IV
14.	Woodworth	III	Woodworth	III	CH-3	
15.	Hill	V	Hill	V	UFV-1	
16.	Pickett 71	VI	Semmes	VII	SJ-2	
17.	Clark 63	IV	Clark 63	IV	Hardee LS	VIII
18.	Essex	V	Essex	V	Orba	
19.	Wells	II	Wells	II	IAC-2	
20.	Beeson	II	Beeson	II	Tunia	
21.	Amsoy 71	II	Amsoy 71	II	Caribe	
22.			Kahala		Kahala	
23.			Rillito	V	Rillito	V
24.					Gasoy 17	VII
25.					James	V
26.			B-1		Crawford	IV
27.					Elf	III
28.					Franklin	IV
29.					Union	IV
30.	Corsoy	II	Corsoy	II	Corsoy	II
31.	Hodgson	I	Hodgson	I	Hodgson	I
32.	Hark	I	Hark	I	Evans	0
33.					Harcor	II
34.	Steele	I	Steele	I	Steele	I
35.	Swift	0	Swift	0	Swift	0
36.	Altona	00			Altona	00

Table 4 : Description of environmental zones and distribution of the third (1975) and fourth (1976) ISVEX.

Environmental zone	Latitude	Elevation (m)	Number of sites 1975	1976
I	≤ 10°59'1/	≤ 500	38	39
II	≤ 10°59'1/	501 - 1,000	5	6
III	≤ 10°59'	> 1,000 2/	6	13
IV	11° - 20°59'	≤ 500	24	24
V	11° - 20°59'	501 - 1,000	1	1
VI	11° - 20°59'	> 1,000	3	7
VII	21° - 30°59'	≤ 500	7	20
VIII	21° - 30°59'	501 - 1,000	0	6
IX	21° - 30°59'	> 1,000	1	3
X	31° - 40°59'	≤ 500	10	15
XI	31° - 40°59'	501 - 1,000	4	5
XII	31° - 40°59'	> 1,000	2	2
XIII	≥ 41° 3/	ALL	2	5

1/≤ = less than or equal to

2/> = greater than

3/> = greater than or equal to

Table 5: List of cultivars included in SPOT during the years 1976, 1977, and 1978.

1976	1977	1978
SJ-2	SJ-2	Acc 2120 1/
CH-3	CH-3	IAC 73-4085
Jupiter	Jupiter	Jupiter
Bossier	Bossier	Bossier
Buffalo	Buffalo	IAC 2
M-79	M-79	IAC 70-25
Hardee LS	Hardee LS	IAC 1
Santa Rosa	Santa Rosa	Santa Rosa 1/
Oribi	GH-23-2-1 (1)	Parana
Rhoda	UFV-1	Mineira
M-98	IAC-73-4013	IAC 73-4013
SJ-1	UFV-1 (BP-20)	Dowling
M-216	Orba	Bedford
Kanrich	Local	

1/ Acc 2120 at 12 sites; Santa Rosa substituted at other sites

Table 6: Plant breeders and list of cultivars included in the first Soybean International Experimental Variety Evaluation (SIEVE) trial to be conducted in 1978

Country	Name and Address of contributor	Plant Breeder	Name of cultivar
Australia	Dr. J. L. Rose Hermitage Research Station Via Warwick, 4370 Queensland, AUSTRALIA	Dr. J. L. Rose	Flegler Purple Semstar
Brazil	Manoel Albina Coelho De Miranda Institute Agronomique de Campinas Caixa Postal, 28 Campinas, Estade de Sao Paulo BRASIL	Remeu Alfonsa de Souza Kiihl	IAC 72-1385 IAC 73-4085
Colombia	Gilberto Bastidas Ramos Instituto Colombiano Agropecuaria ICA Apartado Aereo 233 Palmira (valle) COLOMBIA, S.A.	Gilberto Bastidas R.	ICA L. 109 ICA L. 124 ICA Linea 125
Ecuador	Ing. Eduardo Calero H. Programa de Oleaginosa de C.C. Estacion Experimental Boliche Apartado 7069 Guayaquil, ECUADOR	Ing. Eduardo Calero Ing. Gorky Diaz Ing. Ramon Vinces Ing. Carlos Becilla	Ecuador 1 Ecuador 2 Ecuador 3
Guyana	Herman Adams Central Agricultural Station Mon Repas, East Coast Demarara GUYANA, S.A.	Dr. Kuell Hinson Herman Adams Christian Nwasike	G. twa. 78 G. unk. 78
Honduras	Julio Romero Tropical Agriculture Research Services (SIATSA) La Lima, Cortes HONDURAS, C.A.	Julio Romero	SIATSA-194-A SIATSA-194

BEST AVAILABLE COPY

Table 6 (cont'd): Plant breeders and list of cultivars included in the first Soybean International Experimental Variety Evaluation (SIEVE) trial to be conducted in 1978.

Country	Name and Address of Contributor	Plant Breeder	Name of cultivar
India	Dr. B. B. Singh Senior Research Officer Department of Plant Breeding G. B. Pant University of Agriculture & Technology Pantnagar 263145 INDIA	Dr. B. B. Singh	PK-73-86 UPSM-19 PK-73-94 PK-74-326
	"	Dr. B. B. Singh Dr. K. Hinson	Ankur Alankar
	"	Dr. B. B. Singh Dr. E. E. Hartwig	
Indonesia	Ahmad Dimyati Department of Agronomy Central Research Institute for Agriculture Jalan Merdeka 99 Bogor, INDONESIA	Rodiah Sumarno Ahmad Dimyati Darman M. Arsyad O. Sutrisno	B/1667 1343/1611-1-6-0
Nigeria	Director Institute for Agricultural Research Samaru Zaria, NIGERIA	Unknown	M90 M79 M216
Puerto Rico	Dr. E. H. Paschal II INTSOY Soybean Breeder University of Puerto Rico Mayaguez, PUERTO RICO	Dr. E. H. Paschal, II and others	Acc 2120 IAC 73-4085 IAC 2 IAC 73-4013 IAC 70-25 IAC 1 Mineira Paraná

Table 6 (cont'd): Plant breeders and list of cultivars included in the first Soybean International Experimental Variety Evaluation (SIEVE) trial to be conducted in 1978.

Country	Name and Address of Contributor	Plant Breeder	Name of cultivar
Rhodesia	J. R. Tattersfield Crop Breeding Institute Box 8100 Causeway Salisbury, RHODESIA	J. R. Tattersfield	Impala Kudu
Taiwan	S. Shanmugasundaram Associate Plant Breeder The Asian Vegetable Research and Development Center P.O. Box 42, Shanhua, Tainan 741 Taiwan, REPUBLIC OF CHINA	S. Shanmugasundaram T. S. Young	30217-2-4 30104-1-1 30229-8
Thailand	Dr. Arwooth Nalampang Oil Crop Project Department of Agriculture Bangkhen, Bangkok 9 THAILAND	Dr. A. Nalampang	S.J. 4
U.S.A.	C. E. Caviness Agronomy Department University of Arkansas Fayetteville, AR 72701	C. E. Caviness	R74-1625 R75-3575
	Dr. Kuell Hinson Agronomy Department, 304 Newell Hall University of Florida Gainesville, FL 32611	Kuell Hinson	F67-5132
	Dr. H. R. Boerma 3111 Plant Sciences Building University of Georgia Athens, GA 30602	H. R. Boerma	Ga72-663

Table 6 (cont'd): Plant breeders and list of cultivars included in the first Soybean International Experimental Variety Evaluation (SIEVE) trial to be conducted in 1978.

Country	Name and Address of Contributor	Plant Breeder	Name of cultivar
U.S.A.	Shelby Baker University of Georgia Coastal Plain Experiment Station Tifton, GA 31794	Shelby Baker	GaSoy 17
	Dr. Sam Anand McNair Seed Company P.O. Box 706 Laurinburg, N.C. 28352	Dr. S. C. Anand	McNair 3182 McNair 3181 McNair 3253
Zambia	F. Havaheri Soybean Coordinator P.O. Box 11 Magoye, ZAMBIA	Unknown	MGm 21

Table 7: Responses by cooperators to INTSOY survey conducted in November, 1976.

Questions	Responses		Climatic Regions: Tropical	Climatic Regions: Sub-tropical
If available, would soybeans be used as human food	Yes	%	83	77
	No	%	4	20
Potential for increase in current acreage	Good	%	79	69
	Small or none	%	21	31
Current usage of soybeans	Human food	%	28	17
	Oil	%	38	66
	Meal for livestock	%	32	60
How may INTSOY give assistance in production of soybeans	Providing germplasm	%	41	40
	Providing publications and literature	%	23	26
	Providing assistance for technical problems	%	17	8
	Providing equipment and inoculum & other material assistance	%	6	3
	Provide training for personnel	%	9	20
How may INTSOY provide assistance in utilization of soybeans	Provide information on utilization and processing	%	21	8
	Provide technical assistance for processing and utilization	%	11	11
	Provide material assistance for processing and utilization	%	7	6
	Provide training for processing and utilization	%	2	6

Table 8: Distribution of trial sets among environmental zones for the fourth ISVEX (1976)

Trial set	Number of cultivars	Range of maturity groups	Environmental zone distribution
A	16	III - IX	I, II, III
B	16	III - IX	IV
C	16	III - VIII	V, VI, VII
D	16	II - VI	VIII, IX, X, XI
E	16	I - IV	XII
H	16	00 - IV	XIII
F INTSOY/IITA	8	IV - IX	I, II, III
G INTSOY/SEARCA	8	00 - IV	---

Table 9: Yield of soybean grain and days to maturity of the five highest-yielding soybean cultivars in the fourth ISVEX (1976) conducted under similar ecological conditions in environmental zone I, II, and IV

Environmental zone	Cultivar	Yield (kg/ha)	Days to Maturity
Zone I 0-500 m 0-10° latitude 15 sites	Davis	2525	99
	Forrest	2399	90
	Imp. Pelican	2365	98
	Bragg	2306	95
	Williams	2246	88
Zone II 501-1000 m 0-10° latitude 1 site	Davis	1780	no data
	Bossier	1663	"
	Williams	1538	"
	Hardee	1529	"
	Forrest	1521	"
Zone IV 0-500 m 11-20° latitude 16 sites	Davis	2466	94
	Calland	2356	88
	Forrest	2290	97
	Cobb	2236	92
	Bragg	2206	94

BEST AVAILABLE COPY

Table 10: Yield of soybean grain and days to maturity of the five highest-yielding soybean cultivars in the fourth ISVEX (1976) conducted under similar ecological conditions in environmental zones III, V, VI, VII and VIII

Environmental zone	Cultivar	Yield (kg/ha)	Days to maturity
Zone III	Hill	1990	137
Above 1,000 m	Davis	1934	141
0-10° latitude	Forrest	1867	141
6 sites	Cobb	1697	140
	Imp. Pelican	1661	150
Zone V	Davis	4473	106
501-1000 m	Bragg	4003	99
11-20° latitude	Ransom	3815	100
1 site	Bossier	3513	101
	Forrest	3476	99
Zone VI	Davis	3207	109
Above 1000 m	Essex	3122	104
11-20° latitude	Calland	3144	97
5 sites	Columbus	3111	97
	Ransom	3061	104
Zone VII	Davis	2371	113
0-500 m	Ransom	2358	117
21-30° latitude	Bossier	2306	116
16 sites	Forrest	2227	106
	Bragg	2204	116
Zone VIII	Clark 63	1700	96
501-1000 m	Calland	1652	97
21-30° latitude	Hill	1624	96
2 sites	Forrest	1591	96
	Williams	1510	97

BEST AVAILABLE COPY

Table 11: Yield of soybean grain and days to maturity of the five highest-yielding cultivars in the fourth ISVEX (1976) conducted under similar ecological conditions in environmental zones IX and X

Environmental zone	Cultivar	Yield (kg/ha)	Days to maturity
Zone IX	Ransom	2800	135
Above 1000 m	Woodworth	2678	109
21-30° latitude	Pickett 71	2550	136
2 sites	Williams	2528	106
	Cutler 71	2502	107
Zone X	Williams	3324	118
0-500m	Amsoy 71	3131	115
31-40° latitude	Woodworth	3085	111
8 sites	Beeson	3081	115
	Calland	3025	122

BEST AVAILABLE COPY

Table 12: Yield of soybean grain and days to maturity of cultivars in the joint INTSOY/IITA cooperative trials conducted at six tropical ecological sites in 1976 (environmental zone I, 0-500 m elevation and 0-10° latitude)

Cultivar	Yield (kg/ha)	Days to maturity
Davis	2138	92
TGx 13-3-2644	2136	107
Jupiter	2103	105
TGM 210-1-2363	2026	96
TGM 220-1-2205	1973	103
TGM 256-1-B	1942	98
TGM 294-4-2371	1928	103
Imp. Pelican	1899	91
TGM 255-2-4341	1871	100
TGM 249-4-B	1859	101
Williams	1798	83
Cobb	1782	90
TGx 66-3100	1699	98
Clark 63	1668	85
Bossier	1481	88

BEST AVAILABLE COPY

Table 13: Yield of soybean grain of cultivars at the six locations where the first SPOT was conducted in 1976

Cultivar	Mean yield (kg/ha)						
	Boliche Ecuador 2°S lat 17m	Laguna Philippines 14°N lat 50m	Isabela Puerto Rico 18°N lat 140m	Shanhua Taiwan 23°N lat 8m	Pantnagar India 29°N lat 243m	Salisbury Rhodesia 18°S lat 1506m	All sites
Jupiter	4375 (1)[1/]	421 (11)	1785 (5)	614 (7)	1125 (5)	-	1664 (6)[2/]
M-79	4234 (2)	238 (13	1634 (8)	504 (10)	972 (8)	542 (11)	1354 (11)
Hardee LS	3936 (3)	599 (7)	2108 (1)	1484 (1)	1389 (2)	1500 (9)	1836 (1)
Buffalo	3735 (4)	458 (9)	1237 (12)	683 (6)	333 (14)	2368 (4)	1469 (10)
CH-3	3605 (5)	668 (6)	1635 (7)	1201 (2)	1042 (6)	1882 (6)	1672 (4)
M-216	3605 (6)	149 (14)	1527 (10)	519 (9)	792 (10)	236 (13)	1138 (13
Santa Rosa	3547 (7)	753 (5)	1921 (2)	446 (11)	1042 (7)	2201 (5)	1652 (7)
SJ-2	3443 (8)	1232 (2)	1850 (3)	952 (4)	889 (9)	1639 (8)	1668 (5)
Rhosa	3310 (9)	959 (4)	1226 (13)	552 (8)	558 (12)	2694 (3)	1550 (8)
Oribi	3293 (10)	521 (8)	1417 (11)	313 (13)	722 (11)	2888 (1)	1526 (9)
M-98	3273 (11)	316 (12)	1558 (9)	761 (5)	1236 (4)	465 (12)	1268 (12)
Bossier	3150 (12)	1209 (3)	1706 (6)	333 (12)	1736 (1)	2743 (2)	1813 (2)
SJ-1	2759 (13)	1369 (1)	1816 (4)	1137 (3)	1264 (3)	1736 (7)	1680 (3)
Kanrich	2652 (14)	448 (10)	780 (14)	305 (14)	347 (13)	1305 (10)	973 (14)
Mean	3494	667	1586	700	960	1708	

1/Number in parentheses indicates rank of cultivar within each location
2/Mean of five locations only

BEST AVAILABLE COPY

Table 14: Days to flower of cultivars at the six locations where the first SPOT was conducted in 1976

	Mean days to flower					
Cultivar	Boliche Ecuador 2°S lat 17m	Laguna Philippines 14°N lat 50m	Isabela Puerto Rico 18°N lat 140m	Shanhua Taiwan 23°N lat 8m	Pantnagar India 29°N lat 243m	Salisbury Rhodesia 18°S lat 1506m
Jupiter	46	47	56	30	66	-
M-79	47	51	54	34	66	88
Hardee LS	46	48	49	35	51	81
Buffalo	32	34	39	28	50	67
CH-3	34	33	39	30	48	60
M-216	42	49	57	30	65	88
Santa Rosa	32	32	38	28	41	56
SJ-2	36	34	40	30	50	63
Rhosa	34	32	38	30	42	49
Oribi	32	26	38	29	42	49
M-98	46	49	50	34	66	88
Bossier	32	26	39	29	43	42
SJ-1	32	33	39	29	49	63
Kanrich	33	25	29	28	38	32
Mean	37	37	43	30	51	64

APPENDIX II

International Soybean Virology Research
R. M. Goodman
Assistant Professor, Plant Pathology

Identification of virus-resistant tropically-adapted soybean germplasm.

a. Soybean mosaic virus

Work reported in the 1976-1977 annual report on resistance of tropical soybean germplasm lines to infection by SMV has continued in the present contract year. Eight soybean lines were reported last year to possess resistance in field trials to the Illinois severe isolate (SMV-Il-S) of SMV. Subsequent studies in the greenhouse at Urbana have revealed that certain of these lines were susceptible but difficult to inoculate or were susceptible to another isolate of the virus than that used in the first tests. Currently we regard the following lines as possessing promising resistance or immunity to several isolates of SMV: Buffalo (Rhodesia Agric. I. 72 (2):37), P.I. 341.242, P.I. 324.068, and P.I. 374.193. Work during 1977 and 1978 has been concentrated on Buffalo.

Buffalo was one of the 400 lines planted in July, 1976 at Isabela, Puerto Rico. The planting was in hill plots, and the design was a randomized complete block replicated six times. Ten seeds were planted in each hill. At the primary leaf stage the hills were thinned to six plants and notes taken on the prevalence of SMV infected seedlings arising from seeds. Then all plants in five replicates were inoculated by manually rubbing the leaves with inoculum prepared from SMV-Il-S infected soybeans (cv. Rampage) inoculated 14 to 21 days previously. The inoculum contained 3 ml 0.05 M sodium phosphate buffer, pH 7.0, per gram tissue (fresh weight) plus a small amount of 600 mesh Carborundum and was applied with a sterilized gauze pad.

Symptom readings were taken in late July and early September, when we noted that none of the inoculated Buffalo plants were showing symptoms. We harvested the seeds of this cultivar and tested them further in the greenhouse at Urbana. There we attempted to infect several hundred seedlings over a several month period. In only one case were symptoms seen and this was also the only case in which we could demonstrate the presence of SMV infectivity in the inoculated plants. We do not know if the one plant that became infected was of some other variety, but this result raises the possibility of Buffalo being heterogeneous for SMV resistance. Since Buffalo was not selected for SMV resistance (indeed its having SMV resistance was a surprise to Dr. J. R. Tattersfield who bred this variety, personal communication), this is not an

implausible possibility. Nonetheless, the vast majority of Buffalo plants inoculated at the primary leaf stage and reinoculated 2 to 3 weeks later were immune to infection by SMV-I1-S.

Subsequently, we have isolated over 100 SMV isolates from seeds obtained from the USDA soybean germplasm collections (See contract objective 4). We have placed each of these isolates in one of seven strains based on their ability to infect a range of putatively SMV-resistant cultivars. Buffalo was among the cultivars used for these tests, and it was immune to all isolates except for two which were placed in strain G7. Strain G7 infected all "resistant" cultivars tested including P.I. 96,983 and Tokyo. The symptoms of Strain G7 infection of Buffalo were severe systemic necrosis and bud blight about two to three weeks after inoculation. Strain G7 infecting susceptible soybean cultivars such as Rampage and Clark causes typical mosaic symptoms that are difficult to differentiate from the symptoms caused by Strain G1 which infected none of the resistant cultivars. (It may be of interest to note that when Buffalo is inoculated with Strain G7 only about half the plants become infected. Reinoculation results in infection of all of the previously noninfected plants. Buffalo thus does not appear to possess any immunity to Strain G7 but it is difficult to inoculate.)

We have conducted less exhaustive tests with P.I. 96.983, which is currently in wide use as a source of SMV resistance for temperate soybean improvement. Our results show that this line, like Buffalo, also has a high degree of resistance to many SMV isolates. P.I. 96.983 is susceptible to Strain G7 and also to a seedborne isolate (ISP-29) belonging to Strain G6 isolated by R. M. Goodman in 1975 from Calland soybeans grown at Seville, Spain, to which Buffalo is immune.

Buffalo is a late maturing variety (group VIII) and has a desirable growth habit and other agronomic characteristics which in combination with its immunity to all but the most virulent of SMV isolates will be of particular interest to breeders who require a tropically adapted source of SMV resistance. We have tested the cultivars Geduld and Hernon 147, the parents of Buffalo, kindly supplied to us by Dr. J. R. Tattersfield, Crop Breeding Institute, P. O. Box 8100, Causeway, Salisbury, Rhodesia. Geduld was susceptible to SMV-I1-S but Hernon 147 was immune. No tests with other more virulent SMV isolates have been conducted to date on these parental cultivars. We are now engaged in a genetic study to determine the inheritance of Buffalo's SMV resistance and to incorporate this trait into advanced, tropically adapted soybean cultivars (Ph.D. thesis work by Glenn R. Bowers, Jr.).

Several F_1 plants of the cross Buffalo x Jupiter were inoculated with SMV-I1-S in the field in Puerto Rico in June, 1977. The plants were inoculated twice, once at the primary leaf stage and again two weeks later. We have found Jupiter to be susceptible

to the SMV isolate used in this study. The F_1 plants remained symptomless throughout the growing season. It appears, therefore, that the Buffalo source of SMV resistance is controlled by one or more dominant genes.

The three P.I. lines referred to above are also being tested with the seven SMV strains but the results are not yet available.

b. Cowpea mosaic virus

Two experiments were conducted to screen soybean cultivars for resistance to CPMV-PR infection; one was conducted in the greenhouse at Urbana, and the other in the field at Isabela, Puerto Rico. In the greenhouse experiment, 112 named cultivars (Table 1) in maturity groups 00 to IV were selected. Seeds of each cultivar were planted in three 10-cm pots (5 seeds/pot). Seedlings (10-12 days old) in two pots were left noninoculated for comparison. Symptom development in inoculated plants was recorded until 15 days after inoculation.

Inoculated soybeans showed symptoms of CPMV-PR infection at three to four days after inoculation.

All soybean cultivars inoculated with CPMV-PR became infected. Slight variations in symptoms were observed. Systemic symptoms observed ranged from mild to severe mosaic with severe stunting. Some cultivars (asterisked in Table 1) showed top necrosis and growth was checked. Cultivar Kabbot in maturity group 0 showed local lesions on inoculated leaves but systemic symptoms were mild and plants were only slightly stunted. Cultivars Chusei and Sato-3 in maturity groups III and IV, respectively, showed severe reactions. Infected plants of both cultivars showed local necrotic lesions and top necrosis. Plants were killed within 10 days after inoculation. The number of soybean cultivars showing top necrosis in each maturity group is summarized in Table 2.

In the field screening trial at Isabela, Puerto Rico, 100 soybean cultivars were chosen from maturity group V to X (Table 3). Included in this selection were plant introductions and named cultivars. In addition, 13 lines resistant to feeding by beetles provided by M. Kogan, University of Illinois, were also included.

The plot was 26x35 m and was divided into six 9x9 m subplots. The four meter borders along the sides of the main plot were planted with Improved Pelican soybeans. Ten seeds of each selected cultivar were randomly planted in one of 100 hills (1 m spacing between hills) in each subplot. Seedlings in each hill were thinned to six seedlings/hill. Seedlings in five subplots were mechanically inoculated with CPMV-PR at 8 to 10 days old and those in one subplot were left noninoculated for comparison. Inoculation was repeated seven days later to minimize escapes. Symptoms were recorded at 7 days and 40 days after inoculation. Symptomless plants in the inoculated subplots were marked and seeds from these plants were harvested. These seeds were planted in the greenhouse and tested again for reactions to CPMV-PR infection.

Table 1. Soybean cultivars selected from maturity groups 00 to IV used in screening trials to test for susceptibility to the Puerto Rico isolate of cowpea mosaic virus.

Maturity Group 00

Acme	Manitoba Brown	Sioux*
Flambrau	Pagoda*	
Hidatsa	Pando*	

Maturity Group 0

Early White Eyebrow*	Kabott	Poland Yellow*
Goldsoy	Minsoy*	

Maturity Group I

Blackhawk	Hoosier*	Ottawa*
Bombay	Kagon*	Portugal
Burwell*	Manchu, Montreal*	Renville
Cayuga	Manchuria	Sac
Earlyana	Medium Green*	Soysota*
Elton	Mendota	Wisconsin Black
Giant Green*	Norsoy*	
Habaro*	Ontario*	

Maturity Group II

Aksarben	Kanro	Seneca
Bansei	Kanum	Sousei
Black Eyebrow*	Korean	Toku
Etum	Manchu (Madison)	Waseda
Goku	Protana	Wea
Harosoy	Richland*	Yellow Marvel

Maturity Group III

A. K. (Harrow)	Harman	Miller 67*
Bavender Special A	Illington	Osaya*
Chusei*	Illini	Pennsoy
Cloud	Ilsoy*	Shingto
Columbia*	Jogun*	Willomir*
Dunfield	Lincoln	Wing Jet
Ennis I*	Little Wonder	Wolverine*
Fuji	Manchu	
Guelph	Manchurea 13177	

Maturity Group IV

Aoda*	Green and Black*	Morse
Bethel	Hahto (Michigan)	Norredo
Boone	Harbinsoy	Patoka
Carlin	Higan	Patterson*
Custer	Hongkong	Peking

Table 1 (continued)

Maturity Group IV (cont.)

Cutler	Hurrelbrink	Polysoy
Cypress No. I	Jefferson*	Sato-3I*
Delmar	Kent	Scott*
Ebony	Kingston*	Shiro
Emperor	Kingwa*	Sooty
Fabulin	Macoupin	Wilson
Funk Delicious*	Midwest	

* Cultivars showed top necrosis.

Table 2. The numbers of soybean cultivars showing top necrosis due to infection by the Puerto Rico isolate of cowpea mosaic virus.

Maturity group	Number of cultivars with top necrosis / Number of cultivars tested	Percentage
00	3/7	43
0	3/5	60
I	11/22	50
II	2/18	11
III	9/25	36
IV	9/35	26

Table 2. The numbers of soybean cultivars showing top necrosis due to infection by the Puerto Rico isolate of cowpea mosaic virus.

Maturity group	Number of cultivars with top necrosis / Number of cultivars tested	Percentage
00	3/7	43
0	3/5	60
I	11/22	50
II	2/18	11
III	9/25	36
IV	9/35	26

Table 3. Selected soybean cultivars from maturity group V to X used in reaction tests to infection by the Puerto Rico isolate of cowpea mosaic virus.

Maturity Group V

Hardee Late Selection	SJ-2*	CH #3
UFV-1	Miniera	Santa Rosa
Buffalo	PI 219.653*	C-H25-18-1(2)
SJ-1	ICA-Curive	

Maturity Group VI

C-H31-8-2(1)	Orba
C-H25-18-4(2)	C-H25-18-9(2)

Maturity Group VII

C-H18-10-2(2)

Maturity Group VIII

C-H18-1-1(1)	PI 194.773	PI 239.237
Arisoy*	PI 200.487	PI 240.671
Barchet	PI 200.832	PI 259.538
Seminole	PI 203.399	PI 263.044
Nanda	PI 204,336*	PI 274.506
PI 133.226*	PI 205.903	PI 283.326
PI 159.925	PI 206.258	PI 331.794
PI 164.885*	PI 208.204	PI 341.252
PI 174.854	PI 208.434	PI 374.160*
PI 175.175	PI 209.577	PI 376.845
PI 181.696*	PI 209.837	PI 374.165*
PI 181.698*	PI 210.178	PI 381.657*
PI 183.900*	PI 221.716	

Maturity Group IX

Jupiter	PI 222.549*	PI 324.187
Hardee	PI 240.662*	PI 325.779
PI 181.699	PI 285.097	PI 340.898
PI 205.901	PI 322.691	PI 341.242

Maturity Group X

PI 205.910*	PI 281.907*	PI 341.254*
PI 215.690	PI 281.912*	PI 341.260
PI 240.669	PI 306.702	PI 341.263
Bossier	PI 307.834	PI 374.197*
Siatsa 194	PI 322.692	PI 374.203*
PI 281.894	PI 307.889	PI 281.898*
PI 281.900*	PI 340.902	PI 229.358

Table 3 (continued).

Potential Beetle Resistant Lines

PI 227.687	L76-14-1	L76-70-8
PI 171.451	L76-21-2	L76-CS 76-1
PI 229.321	L76-47-2	L76-175-1
L76-10-3	L76-50-2	
L76-12-14	L76-CS 62-1	

*Cultivars or plant introductions with systemic necrosis symptoms.

All cultivars inoculated with CPMV-PR in this trial became infected. Symptoms were similar to those described for the greenhouse test. Systemic mosaic was common for all cultivars inoculated, with some showing systemic necrosis in addition (asterisked in Table 3). Great variations within cultivars were observed, i.e., some plants in the inoculated hills were apparently healthy, despite the two inoculations employed, and some were infected. In the greenhouse, seedlings emerged from seeds harvested from the symptomless plants were all infected when inoculated with CPMV-PR. It was therefore concluded that the variations observed were not due to genetic variations of the plants but could be due to late emergence of these plants in the field so they were not inoculated. It was also observed in this test that CPMV-PR infection delayed maturity. Virus-infected plants remained green when the healthy plants in the noninoculated subplot reached maturity.

The results from both greenhouse and field screening trials are very interesting in that all soybean cultivars tested were susceptible to CPMV-PR infection. In most of these cultivars, severe symptoms were observed and pods were rarely produced on infected plants.

Results of these screening trials may be useful in view of the type of reactions expected in soybeans to CPMV infection in future screening trials. Should the virus become a threat to soybean production and sources of resistance be needed, cultivars other than those included in our trials must be used in the screening.

c. Whitefly-transmitted virus

I visited the soybean breeding program of Dr. B. B. Singh at the G. B. Pant University, Pantnagar, India in September 1977, to observe the field reactions of soybean germplasm and advanced breeding lines resistant and immune to yellow mosaic virus. P. I. 171.443 and Glycine formosana are the sources of immunity to yellow mosaic virus used by Dr. Singh. As reported last year, we have increased the seed of P.I. 171.443 supplied by Dr. Singh for testing against the whitefly-transmitted Rhynchosia mosaic and Euphorbia mosaic viruses that infect soybeans in the New World.

Identification of soybean germplasm with low incidence of SMV seed transmission

a. Tropically adapted soybeans

The entire tropically adapted soybean germplasm was screened for the incidence of seedborne soybean mosaic virus. These experiments were begun in 1976 and reported on in a preliminary way last year. Seeds from SMV infected field-grown soybeans were harvested and tested over the winter 1976-1977 for SMV seed transmission incidence. Of 400 lines tested, 98 had rates of seed transmission low enough not to be detected when seedlings emerging from 200 seeds were evaluated. These 98 lines along with two known seed transmitters were planted at Isabela, Puerto Rico in May 1977 and again inoculated by hand with the Illinois severe isolate of SMV. At the end of the season, seeds were again harvested from SMV-infected plants and tested in the greenhouse for seed transmission. This time 1000 seeds were planted and data on percentage seed transmission were recorded. These tests are nearly complete and the results indicate at least five lines with no seed transmission of SMV-I1S. These are P.I. 325.779, P.I. 240.664, UFV-1, Arisoy, and P.I. 203.406. Completion of the data collection may result in one or two additions to this list.

Two types of experiments remain before this information could be used in variety improvement for tropical areas. We must demonstrate that the seed nontransmission character is stable and heritable. This we will test by block testing of the lines in the field, inoculating the lines with SMV and examining progeny seed in large numbers in field plots for evidence of seed transmission; we will also conduct some crossing with a line showing high incidence of seed transmission to determine if seed nontransmission is simply inherited. In a second type of experiment we shall test these lines with other strains of SMV to determine if lines that are seed nontransmitters of one SMV strain are also nontransmitters of other strains. These experiments, which are time consuming, will begin in the 1978-79 contract year.

b. Northern germplasm

Last year's report described the early stages of our trials looking at seed transmission rates in maturity groups II and III germplasm. The 35 lines selected in 1976-77 for testing during 1977-78

were chosen because they had low rates of seed transmission and because they exhibited slight, if any, seed coat discoloration (mottling), which is an undesirable symptom on the seed produced by SMV infected plants.

Results this year showed that seed coat mottling cannot be selected against in this type of experiment. The incidence and severity of mottling was high in all lines. But the incidence of SMV seed transmission was low. Fourteen lines were identified that exhibited no evidence of SMV seed transmission from seedlings emerging from 1000 seeds. These were Cloud, Manchu 2204, Mukden, Virginia, F.C. 31.678, P.I. 60.279, P.I. 68.680, P.I. 70.019, P.I. 70.036, P.I. 88.303, P.I. 91.115, P.I. 92.684, P.I. 92.718-2 and P.I. 360.835.

Further tests with group II and III lines discarded last year due to high seed coat mottling incidence will be tested in contract year 1978-79. Also, tests will be conducted to determine the incidence of seed transmission in the above lines inoculated with other SMV strains.

Detection of SMV in seeds and seed parts by ELISA

a. This research is cooperative work supported in part by the INTSOY contract and in part by grants from the Illinois Crop Improvement Association and the Illinois Agricultural Experiment Station. The purpose of the work was to develop a procedure for accurate and reliable testing of soybean seeds for the presence of soybean mosaic virus that would be quicker, easier, and require less greenhouse space than the infectivity index method utilizing local lesions on Top Crop beans described in last year's report.

It has been our goal this past year to begin development of a mass-screening test for the detection of virus in soybean seed lots that is both effective and easily managed. Coupled with this objective has been the production of high quality rabbit anti-SMV sera for use in testing.

This past year has been spent cataloguing and titering the existing stock of antisera, culturing and purifying SMV, and producing a fresh supply of high titer SMV antiserum. We have also been exploring various methods of testing for SMV in seeds and testing virus activity in seeds by the local lesion method. The local lesion tests have indicated that virus is present in detectable amounts in a single seed.

Unfortunately, mottled seed coat color is not a reliable indicator of the presence or transmissibility of virus. The local lesion test in itself is also not a good test since it requires greenhouse space, test plants, incubators, and time. Our original plan of using double diffusion through agar has met only limited success. SMV does not easily diffuse through agar and must be broken with pyridine or SDS, both of which can cause spurious results. When

ground seeds were used the high carbohydrate content also caused poor results by leaving thick milky rings while diffusing through the agar. Parts of germinated plants can be embedded in agar but this plan also had its drawbacks. Technically, either of these tests could probably be made workable but both are time-consuming, tedious, and use large amounts of antiserum.

Another approach has been to use a latex flocculation test. Latex spheres can be made to adhere to antibodies. When the latex-sensitized antibodies are exposed to virus in capillary pipettes or spot plates, visible flocculant complexes of virus and antibody appear. This test has the advantage of speed since it may be read in fifteen minutes to one hour. This test is under consideration but as of now it is our second choice because it is not always easy to read, requires some special equipment, and the latex-sensitized antibodies must be used in fairly concentrated amounts.

Our first choice so far has been ELISA. ELISA is a mnemonic for enzyme-linked immunosorbent assay. ELISA is in theory a complicated test but in practice it is elegantly simple, sensitive, and conservative of materials. Since the test uses antisera and other materials and reagents in almost micro amount it should also prove to be very inexpensive. ELISA is also sensitive to very small amounts of virus, is easy to do and to read, and requires very little special equipment.

ELISA works because it is possible to bond an enzyme to the gamma globulin fraction of antiserum and to bind globulin to virus. In the presence of the specific substrate there is a visible measurable reaction. This reaction is specific, local and sensitive.

The kind of assay we have used is the double-antibody method. Unlabelled antibody is bound electrostatically to the surface of a polystyrene microhaemagglutination plate. Virus, if present, binds to the unlabelled antibody. In turn, the enzyme-labelled antibody binds to the virus and in the presence of substrate shows a color-change reaction. If there is no virus there will be no labelled antibody bound and hence no color change. The virus is the limiting factor in this test.

The enzyme we use is alkaline phosphatase. We first determined how to do the test and that it does work. We have also prepared labelled and unlabelled gamma globulin and all the necessary buffers and solutions. The time factor seems to be the major drawback to this test since there is at least one overnight incubation required. However, once the preparations are made the actual reaction takes thirty minutes.

We have also conducted studies to show that seeds, seed parts (testa, endosperm and embryo), and various plant parts (roots, leaves, stem sections, etc.) can be used as sources of antigen

for the test. In an experiment, we sensitize a plate and store it until use. When required we thaw the plate, wash it, crush pieces of tissue from the seeds or plant to be tested into a small volume of saline on the plate, incubate, wash, add various reagents in order with appropriate washes, and take the data all within a 2-3 hour period. Thus in a half day a single operator can test 60 to 180 samples.

We have also done extensive tests comparing the infectivity method with ELISA using seed parts and various other types of tissues in which the presence of SMV was unknown or concealed from the person doing the test. We have found very high (virtually perfect) correlation between these two tests.

b. Studies on the mechanism of SMV seed transmission

In the 1976-1977 annual report, we reported studies on the detection of SMV in reproductive parts of soybean seeds throughout the reproductive growth of the plant. We concluded that, in plants inoculated during vegetative growth stages, all flowers and immature seeds and pods became infected. As seeds and pods matured the presence of infective virus decreased. When two soybean varieties were compared, the variety with relatively high incidence of virus transmission through seed also had a high incidence of infective virus remaining in mature seed; the variety with low seed transmission incidence had a low incidence of infective virus in mature seed.

Our studies in the current year were designed to locate infective virus in mature seed parts and to compare infectivity tests with ELISA as methods to study seed infection by SMV. In one study, the incidence of infective SMV from the testa, cotyledon, embryo or entire seed was measured at R6, R7, and R8 (R7 corresponds to physiological maturity; R8 is harvest maturity). The results (Table 4) indicate that seed transmission is associated with the presence of infective SMV in embryos, as the percentage seed transmission by Midwest and Merit was about 40% and 0%, respectively.

In the interest of testing whether ELISA could be used to predict the incidence of seed transmission, we tested seed parts both by infectivity and ELISA. The frequency of samples that were positive by ELISA and negative by the infectivity test (Table 5) led to a series of experiments in which detection of SMV in seed coats of Midwest soybeans was tested by the two methods. The results (Table 6) indicate that SMV antigen is present, which gives a positive ELISA result, but that infectivity is absent. This suggests that virus was present at an earlier stage in seed development and was inactivated during maturity, leaving noninfective antigen. The results also showed that the virus antigen was in the seed coat rather than on its surface and that the sterilization of the seed coat surfaces with trisodium phosphate did not affect the results with either detection method.

Table 4. Incidence of infective SMV in seeds and seed parts of Midwest and Merit soybeans tested at 3 late stages of maturity.

Soybean Variety	Maturity Stage	Percentage seeds or seed parts with infective SMV			
		Seed	Testa	Cotyledon	Embryo
Midwest	R6	81.3	81.3	17.3	21.3
	R7	90.7	86.7	36.0	42.7
	R8	36.0	2.7	32.0	33.3
Merit	R6	93.3	89.3	21.3	16.0
	R7	88.0	86.7	9.3	6.7
	R8	0.0	0.0	0.0	0.0

Table 5. Comparison of ELISA and infectivity tests for detection of SMV in seed parts dissected from the R8 seeds of SMV-infected Midwest soybeans.

Method	No. tests positive/No. samples tested		
	Testa	Cotyledon	Embryo
ELISA	72/75	26/75	25/75
Infectivity	2/75	24/75	25/75

The implications of the above results are that SMV seed transmission is the result of embryo infection and ELISA cannot be used on whole seeds to accurately predict the incidence of seed transmission in a seed lot. Dissection of seeds or testing of germinated seedlings should be used if ELISA tests are to be employed in seed certification.

Table 6. Detection of SMV in seed testas by ELISA and infectivity.

Experiment	Treatment[a/]	No. samples positive/No. samples tested	
		ELISA	Infectivity
1	Sterilized	25/25	0/25
	Not sterilized	25/25	0/25
2	Sterilized	25/25	0/25
	Not sterilized	25/25	0/25
3	Sterilized	25/25	0/25
	Not sterilized	25/25	0/25

[a/] Surface sterilization of R8 seeds was by soaking 1 minute in 10% trisodium phosphate followed by rinsing in distilled water.

c. Studies on the virulence of seedborne SMV isolates from the USDA soybean germplasm collections.

SMV is the most widespread soybean virus and it poses an important threat to soybean production in areas where aphid vectors are plentiful and active. Our research on SMV is based on a need to generate information that may be used to control SMV spread in the field. Since the virus is seedborne we have given some attention to reducing the prevalence of seedborne virus in our lines and varieties. We have also studied the use of genetic resistance to infection by SMV. Other workers have released varieties putatively resistant to SMV infection but no one had previously investigated the possibility that various SMV strains differing in virulence might exist. We have therefore collected SMV isolates from a wide range of soybean germplasm and tested the virulence of the isolates against six putatively resistant and two known susceptible soybean varieties. Seeds were obtained from the USDA soybean germplasm collections at Urbana, Illinois, and Stoneville, Mississippi.

Accessions selected for virus isolation were from the most recent introductions and from as wide a geographical range as possible. All seeds used, however, were produced in the U.S., and thus it cannot be assumed that the geographical origin of the accession is also the origin of the virus isolates. Twenty-three accessions from the Urbana germplasm collection and 53 from the Stoneville germplasm collection were used as sources of seedborne SMV.

About 90 soybean seeds of each accession were planted in a sand-bench in the greenhouse. Soybean seedlings with mosaic symptoms two weeks after planting were transplanted into composted, autoclaved soil in clay pots. The diseased plants were later used to prepare inoculum for inoculation of soybean differentials.

Inoculum was generally prepared one week after transplanting from trifoliolate leaves showing mosaic symptoms. Four or five trifoliolate leaves from diseased plants were homogenized in buffer, a small amount of Carborundum (600 mesh) was added, and the inoculum was applied by rubbing the leaves of test plants.

SMV samples were also collected from field-grown soybeans. Thirty four SMV-infected plants found in the soybean germplasm field trial at Urbana, Illinois in 1977 and 27 samples from the field trial at Stoneville, also in 1977, were collected. Field collections at Stoneville were made on June 10, 1977 when the plants were at the primary leaf stage. Leaf samples in vinyl bags were brought by airplane from Stoneville to Urbana and kept in the refrigerator before inoculations on Rampage soybeans in the greenhouse were made. At Urbana, field collections were made on July 7, 1977, when the plants had produced the third trifoliolate leaves.

Diseased soybeans collected from the field were used to inoculate the primary leaves of Rampage soybeans, and Rampage soybean leaves showing mosaic symptoms about ten days after inoculation were used as inoculum to inoculate soybean differentials. When Rampage soybeans were inoculated with inoculum prepared from field-collected samples, the inoculum was indexed by the Top Crop bean index method to comfirm that SMV was present. Isolates showing symptoms in Rampage soybeans and inducing local lesion formation on the detached leaves of Top Crop beans were used for further differentiation on the basis of reactions on soybean differentials.

The inoculated plants were kept in a greenhouse in which temperatures ranged from 18 - 30 C. Supplemental lighting was from fluorescent lights to give a daily light period of 14 hr. To test whether temperature affected symptom development in soybean differentials, experiments were conducted with representative isolates of each group in growth chambers maintained at 23 $\pm$ 1 C, and 30 $\pm$ 1 C with 14 hr light and 10 hr dark periods.

All SMV isolates were classified into groups on the basis of reactions of soybean differentials. Virus isolates selected from each reaction group to be used for further study were maintained by inoculation to soybean plants in the greenhouse. The soybean cultivar Rampage was used to maintain the isolates.

Soybean differentials were prepared by seeding five to six seeds of each differential in a clay pot, and all germinated seedlings

were inoculated. Ten pots with five to six plants of each differential were used for inoculation of each representative isolate at the first inoculation. This was repeated with five pots with five to six plants after the first test was completed.

The research approach was to collect soybean mosaic virus isolates from sand-bench and field grown soybean seedlings and to mechanically inoculate a range of soybean cultivars including resistant and susceptible types. Buffalo, Davis, Kwanggyo, Marshall, Ogden and York soybeans were the SMV resistant cultivars used. Rampage soybeans were used as an SMV-susceptible cultivar and Clark was used as moderately susceptible to SMV.

Isolates were differentiated on the basis of major differences in symptoms such as local lesions on inoculated primary leaves and the occurrence of systemic symptoms and whether or not the symptoms involved necrosis or mosaic patterns.

Appropriate tests (ELISA, host range and other serology methods) were used to show that the viruses isolated from the seed and field samples were SMV and contained no other viruses.

Twelve out of 53 soybean P.I.s from the Stoneville germplasm collection, and seven out of 23 soybean P.I.s from the Urbana germplasm collection, produced one or more seedlings with virus symptoms. From these 19 soybeans, 37 isolates of SMV were obtained. Each isolate was obtained from a single plant showing mosaic symptoms.

Clark and Rampage produced mosaic symptoms when inoculated with each of the 37 isolates. In contrast, only four isolates caused symptoms in Davis and York. Twelve of the 37 isolates caused necrotic symptoms in Marshall and nine of the 37 isolates caused necrosis in Ogden. Kwanggyo produced necrosis only when inoculated with isolate 32-2, and none of the isolates obtained from seeds caused visual or latent infection in Buffalo.

The 37 seedborne isolates were classified into five groups according to the reactions they caused in the six soybean cultivars used as differentials (Table 7). Representative isolates of each group were selected for further investigation.

Isolate 32-2 (Table 7) was the only unique isolate obtained in this series of tests. Three isolates showed reactions similar to those caused by isolate 016-2, nine isolates gave reactions similar to those of isolate 83-2, eight isolates gave reactions similar to those of isolate 60, and sixteen isolates gave reactions similar to those of isolate 019-2.

Twenty-seven isolates from 20 soybeans in the USDA Stoneville germplasm collection grown at Stoneville, Mississippi, and 34 isolates from 34 soybeans in the USDA Urbana germplasm collection

of soybean grown at Urbana, Illinois, were obtained. Each isolate was inoculated to Rampage soybeans to provide inoculum for inoculation of the soybean differentials. All isolates produced mosaic symptoms in Rampage soybeans.

Table 7. Reactions of soybean cultivars as differentials to isolates of soybean mosaic virus obtained from seeds of soybean germplasm collections.

Soybean Cultivars	Symptoms caused by SMV isolates[a]				
	32-2[b]	016-2	83-2	60	019-2
Clark	-/M	-/M	-/M	-/M	-/M
Rampage	-/M	-/M	-/M	-/M	-/M
Davis	-/M	-,N/M,N	-/-	-/-	-/-
York	-/M	-,N/M,N	-/-	-/-	-/-
Marshall	-/-	N/N	N/N	N/N	-/-
Ogden	-/-	N/N	N/N	-/-	-/-
Kwanggyo	N/N	-/-	-/-	-/-	-/-
Buffalo	-/-	-/-	-/-	-/-	-/-

[a]:Reactions on the inoculated primary leaves/reactions on the noninoculated trifoliolate leaves -: Symptomless, no virus was detected by Top Crop indexing, M:Mosaic symptoms, N:Necrosis

[b]:Designation of representative isolate of SMV for each group

Seven isolates showed the same reactions on the differentials as the 32-2 isolate. Eight isolates resulted in the 83-2 isolate type reactions. Sixteen isolates showed the same reactions as the 60 isolate type reaction group, and eleven isolates belonged to the 019-2 isolate type reaction group.

As shown in Table 8, isolate s 29 represents the 019-2 type, u 484 represents the 60 type, u 35 represents the 83-2 type, and s14-3 represents the 32-2 type. However, two other reaction types were discovered, which were not found in the isolates obtained from the seeds planted in the sand bench. Isolates u 670 and u 613 produced necrotic symptoms in Buffalo. The u 670 isolate caused mosaic symptoms in Clark, Rampage, Davis, and York, and necrosis in Marshall, Ogden, Kwanggyo, and Buffalo. Because it infected all of the differentials, it was the most virulent of all the isolates of SMV tested in this study.

A second group of isolates that differed from those previously discovered were those showing the same reactions as isolate u 427. Clark, Rampage, Davis, and York were susceptible to infection by u 427 type isolates and produced mosaic symptoms. Marshall and Kwanggyo produced necrosis while Ogden and Buffalo remained symptomless. Eleven isolates showing reactions similar to the u 427 isolate were found.

No isolates showing the same pattern of reactions as that caused by isolate 016-2 were obtained from either field collections.

Ninety-eight isolates of SMV, 37 from seeds and 61 from field samples, thus were classified into seven different strains based on the symptoms they produced in soybean differentials. Those are designated as SMV-G1, SMV-G2, SMV-G3, SMV-G4, SMV-G5, SMV-G6, and SMV-G7 for isolate types 019-2, 60, 83-2, 016-2, 32-2, u 427, and u 670, respectively (Table 9).

Of the 98 isolates of SMV used in these tests, SMV-G1 includes 27 isolates, 11 from seeds and 16 from field samples; SMV-G2 includes 24 isolates, 8 from seeds and 16 from field samples; SMV-G3 includes 17 isolates, 8 from seeds and 9 from field samples; SMV-G4 includes 3 isolates, all from seeds; SMV-G5 includes 8 isolates, one from seed and 7 from field samples; SMV-G6 includes 17 isolates, all from field samples; and SMV-G7 includes two isolates from field samples.

Grouping was on the basis of reactions of one or two plants of each soybean differential in tests conducted between April and September, 1977. Isolates classified early in this period were used subsequently as standards to compare their reactions with isolates tested later. After the initial tests were completed, the one isolate from each group indicated above was selected. The representative isolates were then tested together in the greenhouse two times, and in the growth chambers one time; the results showed that the reactions were consistent and reproducible. The latter tests were conducted during November and December, 1977.

Table 8. Reactions of soybean cultivars as differentials to isolates of soybean mosaic virus obtained from field samples collected from the USDA soybean germplasm collections.

Soybean cultivars	Symptoms caused by SMV isolates[a]					
	u 670[b]	u 427	s 14-3	u 35	u 484	s 29
Clark	-/M	-/M	-/M	-/M	-/M	-/M
Rampage	-/M	-/M	-/M	-/M	-/M	-/M
Davis	-/M	-/M	-/M	-/-	-/-	-/-
York	-/M	-/M	-/M	-/-	-/-	-/-
Marshall	N/N	N/N	-/-	N/N	N/N	-/-
Ogden	N/N	-/-	-/-	N/N	-/-	-/-
Kwanggyo	N/N	N/N	N/N	-/-	-/-	-/-
Buffalo	N/N	-/-	-/-	-/-	-/-	-/-

a/: Reactions on the inoculated primary leaves / reactions on the noninoculated trifoliolate leaves -: Symptomless, no virus was detected by Top Crop indexing, M : Mosaic symptoms, N : Necrosis

b/: Designation of representative isolate of SMV for each group

Table 9. Reactions of soybean cultivars as differentials to each group of soybean mosaic virus isolates obtained from the USDA soybean germplasm collections.

Soybean cultivars	Symptoms caused by SMV isolates[a]						
	SMV-G7	SMV-G6	SMV-G5	SMV-G4	SMV-G3	SMV-G2	SMV-G1[b]
Clark	-/M	-/M	-/M	-/M	-/M	-/M	-/M
Rampage	-/M	-/M	-/M	-/M	-/M	-/M	-/M
Davis	-/M	-/M	-/M	-,N/M,N	-/-	-/-	-/-
York	-/M	-/M	-/M	-,N/M,N	-/-	-/-	-/-
Marshall	N/N	N/N	-/-	N/N	N/N	N/N	-/-
Ogden	N/N	-/-	-/-	N/N	N/N	-/-	-/-
Dwanggyo	N/N	N/N	N/N	-/-	-/-	-/-	-/-
Buffalo	N/N	-/-	-/-	-/-	-/-	-/-	-/-

[a]: Reactions on the inoculated primary leaves / reactions on the noninoculated trifoliolate leaves
-:Symptomless, no virus was detected by Top Crop indexing, M:Mosaic symptoms, N:Necrosis

[b]: Designation of SMV isolate group

The results in the growth chamber when the temperature was 24C were similar to those obtained in the greenhouse. Necrotic symptoms were more conspicuous at 30±1 C than at 24±1 C, but no qualitative differences in reactions were noted at the higher temperature.

Inoculation of soybean differentials with seven representative SMV isolates showed consistent and distinguishing differences among the isolates. The results of these tests also indicated differences among the soybean cultivars used as differentials for these tests, suggesting that the various "resistant" varieties used possess different genetic systems for resistance to SMV.

The necrotic symptoms observed in SMV-infected Buffalo, Davis, York, Kwanggyo, Marshall, and Ogden soybeans were essentially the same regardless of the responsible isolate of SMV: they were also quite similar to those described by previous workers. Necrosis caused by SMV in resistant cultivars was different from that caused by tobacco ringspot virus which does not generally cause systemic infection to form lesions and does cause severe stunting of the plants. The results obtained in this study confirm previous observations which suggested that necrotic symptoms caused by SMV are associated with virulent isolates infecting soybean cultivars resistant to less virulent isolates. The occurrence of systemic necrosis caused by virulent strains of SMV is a serious threat to efforts towards improving soybeans for SMV-resistance, a problem that has already occurred in production fields in South Korea.

SMV isolates infecting Davis, York, and Buffalo are reported here for the first time in the U.S. In addition to the susceptibility of those soybean cultivars, it may be significant that at least two isolates in SMV-G7 and one isolate in SMV-G6 (ISP-29) are able to cause severe necrotic symptoms or mosaic symptoms in P.I. 96.983, which has been shown previously to have resistance to SMV and is now in wide use as a source of SMV resistance for U.S. soybean variety improvement.

The most widely grown soybeans, Wayne, Clark, Lee, Amsoy, Corsoy, Bragg, Dare, Chippewa, Beeson, and Harosoy, not only have a narrow genetic background but they also are related to Clark, Davis, Ogden, Rampage and York which were susceptible to many of the SMV isolates used in this study. The information obtained in this study will be valuable for re-evaluation of all 'resistant' soybean cultivars or lines and for more satisfactory evaluation of lines for SMV resistance in the future. These newly recognized SMV strains will also be useful for genetic studies on host-virus interactions, and for studies on other biological properties of the virus such as seed transmission, aphid transmission and serological properties.

There has been no evidence that the SMV isolate groups contain viruses other than SMV according to symptomatology, Top Crop

indexing, serology and host range tests. However, the possibility that one or more of the SMV groups could consist of a mixture of SMV strains, especially in isolates obtained from field samples, has not been completely eliminated.

d. Genetic studies on cowpea mosaic virus.

Studies on the genetics of cowpea mosaic virus (CPMV) which began last year were concluded. Our objective was to determine whether strains of this multicomponent, beetle transmitted virus can recombine to form new pathotypes. Two natural strains of CPMV were used which differed in symptomatology and antigenic specificity. The results, which have been published, showed that genetic pseudorecombination can occur. Our work on this virus is being concluded because the virus does not appear to spread to soybeans readily even when infected cowpeas are interplatned with soybeans.

c. Studies on the DNA genome of bean golden mosaic virus, a whitefly-transmitted plant virus.

Our work on this novel plant virus which was begun last year has continued. Bean golden mosaic virus is the first whitefly-transmitted virus discovered and characterized. We showed that the virus contains an unusually small single-stranded DNA genome molecule. The results of these studies have been published. Several basic questions, having to do with how such a small DNA molecule can cause disease and whether the virus is multicomponent or not, have not been resolved and work is therefore continuing.

f. Preparation and testing of a specific antiserum to BGMV.

BGMV was purified and used to immunize a 6 lb. New Zealand white rabbit. Weekly intramuscular injections were given of virus emulsified in Fruend's complete adjuvant. Sera were obtained from the rabbit at various times. The dilution endpoint titer of the serum after 4 weeks reached 1/320 when tested against the sap of infected plants in Ouchterlony double diffusion tests.

Although the virus used for injection was highly purified, antibodies specific for phytoferritan were also present in the BGMV antiserum. The endpoint titer of the phytoferritin antibodies was usually less than 1/32, however, and the antibodies could be cross absorbed with purified phytoferritin. Since BGMV-infected plants produce large amounts of phytoferritin and since phytoferritin levels in healthy plants are very low, the presence of phytoferritin in immunogens, or antibodies specific for phytoferritin in virus antisera, must be reckoned with in the interpretation of serological tests with this virus. The BGMV antiserum has been used to study the sedimentation components associated with BGMV and has been distributed to cooperators in Nigeria, India, Israel and Brasil for testing.

g. Ultrastructure of infection by BGMV.

A study has been made of the time course and ultrastructural aspects of BGMV infection of bean cells using the electron microscope. The work, which has been accepted for publication, showed that BGMV infects the nuclei of bean cells associated with the phloem. Dramatic ultrastructural alterations occur in the infected nuclei that are unlike any caused by previously known plant viruses. We have already used these observations to diagnose a disease from a weed plant common in Costa Rica as caused by a whitefly-transmitted virus that infects soybeans in tropical America.

h. Attempts to purify and characterize whitefly-transmitted viruses from soybeans.

Unsuccessful attempts to purify soybean-infecting whitefly-transmitted viruses were made in early 1977 in cooperation with Dr. Julio Bird, University of Puerto Rico, and in late 1977 in cooperation with Dr. J. Vetten, International Institute for Tropical Agriculture, Nigeria. A cooperative investigation is now underway with Dr. S.P.S. Beniwal to see if electron microscopy can be used to diagnose soybeans infected with mung bean yellow mosaic viruses from India.

i. Attempt to purify the agent causing lima bean golden mosaic in Nigeria.

In collaboration with Dr. J. Vetten of IITA, Nigeria, we attempted but failed to purify the lima bean golden mosaic agent. This is suspected to be a virus related to BGMV. Serological tests are now underway at IITA to check this possibility more directly.

Yield losses and field transmission of soybean viruses.

a. Soybean mosaic virus

These studies are cooperative work with the INTSOY entomologist and are covered in the report by Dr. M. E. Irwin.

b. Cowpea mosaic virus

The discovery of natural infection of soybeans by CPMV-PR and the severe disease caused by this virus (see 1976-77 contract report) led to a series of experiments to determine the likelihood of CPMV-PR becoming a problem in soybean production. The significance of CPMV infection of soybeans in soybean production would depend primarily on the transmission of the virus from a primary source to nearby plants by beetles, the effect of the virus infection on soybean seed yield, and the susceptibility of

different soybean cultivars to the infection. To explore these factors, three types of studies were conducted. Transmission of CPMV-PR by beetle vectors in the field and greenhouse was tested, yield reductions in soybeans due to CPMV-PR infection were measured, and soybean cultivars were screened to identify possible sources of resistance.

Transmission of CPMV-PR from Cowpeas to Cowpeas and Soybeans. Bean leaf beetles, *Ceratoma trifurcata*, were collected from a soybean field at Tolono, Illinois in August 1976. Individual beetles were allowed to feed on a single healthy cowpea seedling (10 days old) for two days immediately before use in the transmission experiments. These cowpea plants were maintained in the greenhouse for one month to assure that each beetle was not viruliferous. Acquisition feeding was by allowing each beetle to feed for 48 hours on trifoliolate leaves from cowpea plants inoculated with CPMV-PR 14 days earlier or on leaves from comparable healthy plants held in petri dishes (1.5x6 cm). Leaf turgidity was preserved by including a small piece of moistened filter paper in each petri dish. Inoculation feeding, which was also for 48 hours, was by confining each beetle to each healthy cowpea or soybean seedling (10 or 12 days old, respectively) using cylindrical (5x20 cm) cellulose nitrate cages. Twenty seedlings each of cowpea and soybean were exposed to beetles previously fed on infected leaves and 10 each to beetles previously fed on healthy leaves. Inoculated cowpeas and soybeans were maintained in the greenhouse for three weeks for symptom development. Leaves from symptomless plants were used as inoculum in indexing to Scotia beans.

None of the field-collected beetles were viruliferous since no cowpea plants exposed to individual beetles showed any viruslike symptoms. All cowpea plants and three out of 20 soybean plants inoculated by beetles fed on infected leaves during acquisition feeding became infected. Symptoms typical of CPMV-PR appeared on cowpeas 5 days and on soybeans 13 days after inoculation feeding. No transmission was obtained from plants exposed to beetles previously fed on healthy leaves. Transmission rates from cowpeas to cowpeas and from cowpeas to soybeans in my experiments are in very good agreement with those reported by Jansen and Staples in 1970.

Field Spread of CPMV-PR. Two similar experiments were conducted at Isabela, Puerto Rico; one was planted on 29 October 1976 (winter) and the other on 24 May 1977 (summer). Plot size for both experiments was 35x26.5 m. Cowpeas were planted in rows parallel to the long axis with 0.65 m between rows. The center 21 rows of cowpeas were marked into two small subplots which had 5 m borders from the plot edges and between subplots. In these two subplots, every other row of cowpeas was mechanically inoculated with CPMV-PR when the plants were at the primary leaf stage (10 days old). Two weeks after planting, all noninoculated cowpea plants were removed and replaced with soybean (cultivar Improved Pelican). The spread

Table 10. Transmission rates of the Puerto Rico isolate of cowpea mosaic virus from cowpea source leaves to cowpeas and soybeans by the bean leaf beetle, *Ceratoma trifurcata*.

Source leaves	Test plant	Transmission[1]	% Transmission
Infected	Cowpeas	20/20[2]	100
	Soybeans	3/20	15
Healthy	Cowpeas	0/10	0
	Soybeans	0/10	0

[1]Beetles were allowed a 48-hr acquisition feeding period followed immediately by the same period of inoculation feeding.

[2]Transmission was expressed as number of plants infected over number of plants inoculated.

of the virus was determined by observing the number of soybean plants infected with CPMV-PR which was confirmed by serological tests. The first observations were during the seventh week after planting, after which infected cowpea plants in one subplot were removed to induce beetle migration to nearby soybeans. Cowpeas in the other subplot were left undisturbed for comparison. Second observations were during the eleventh week after planting of cowpeas.

Many soybean plants with virus-like symptoms were found during the first observations but results from serology tests indicated that these plants were not infected with CPMV-PR. At this stage of soybean growth and development, the characteristic injury on leaves caused by feeding of the bean leaf beetle was very low (less than 5% of leaf area at the canopy top was consumed) in the winter experiment. The injury in soybeans caused by beetle feeding was about 5-10% consumption of the leaf area at the canopy top in the summer experiment. Again, no CPMV-PR infected soybean plant was found.

During the second observations, one CPMV-PR infected soybean plant was found in the subplot where infected cowpea plants were removed in the winter experiment. No CPMV-PR infected soybean plant was found in the summer experiment. Soybean plants in the summer experiment were infested with the velvet bean caterpillar (*Anticarsia gemmatalis*) and the plants had to be sprayed with insecticides two weeks before the second observations.

The low transmission observed during winter experiment could be due to reduced beetle activity and population during the winter season. It may be because cowpea plants were infected with powdery mildew at one week before the first observations. Powdery mildew infected plants had mycelium-covered leaves with less green color. These leaves could have been less attractive to beetles since injury in cowpeas due to beetle feeding was also low. During the summer experiment, however, beetles were prevalent as indicated by the degree of injury caused by beetle feeding but transmission did not occur. This situation cannot be explained with our present knowledge of the complex virus-vector-host relationship. The transmission rate (15%) of CPMV-PR from cowpeas to soybeans, indicated from greenhouse studies, should be sufficient for secondary spread of the virus in the field. This is compatible with our previous observations of naturally infected soybeans in Puerto Rico, as beetle transmission seems to be the only means of the spread of the virus in the field.

Yield Reductions in Soybeans Due to CPMV-PR Infection. Three similar experiments were conducted using Improved Pelican soybeans planted on 29 December 1976, 13 May 1977, and 1 July 1977. The experimental design was a randomized complete block, split plot with four replications in the first experiment and five replications in the other experiments. Each subplot consisted of five

treatment rows. Each treatment row in the first experiment was five meters long; in later experiments rows were six meters long. Treatment rows in each subplot were separated by one row of non-treated soybeans on each side. Spacing between rows was 60 cm. The five treatments each subplot received were inoculations of 0, 25, 50, 75, and 100% of plants at either the primary leaf stage or the midbloom stage. Plants were left noninoculated for 0% inoculation and every fourth plant, every other plant, three out of four plants, and all plants were inoculated for 25, 50, 75, and 100% inoculations, respectively.

Soybeans were mechanically inoculated when they were at the primary leaf stage (8 to 10 days after planting) or at the midbloom stage when approximately half of the flower buds had color. Plots were hand-harvested. Seeds from the 0.5 m ends of each treatment row were not included in yield measurements to minimize edge effects. Seeds were dried to a uniform moisture content of 10% (29 December 1976 planting) or 11% before being weighed.

Inoculated soybean plants in the field showed typical symptoms of CPMV-PR infection within 5 to 7 days after inoculation. Infected plants were counted several weeks after inoculation to verify that all or nearly all of the inoculated plants became infected. In the experiment planted 13 May 1977 the primary leaf stage inoculation was repeated 10 days after the first inoculation since some inoculated plants were not infected after the first inoculation.

Yield data from all treatments were recorded as gram seed weight per treatment row. The mean yields from all treatments were calculated and compared to that of the noninoculated control (Figure 1). Within one standard deviation range, a straight line showing the relationship of these plots could be drawn except for the primary leaf stage inoculation in the experiment planted 1 July 1977. Correlation coefficients (r) of these plots for the primary leaf stage and the midbloom stage inoculations are -0.9839 and -0.9899, -0.9744 and -0.9748, and -0.9202 and -0.9503, respectively for experiments planted 29 December 1976, 13 May 1977, and 1 July 1977. All values of 'r' except that for the primary leaf stage inoculation from experiment planted 1 July 1977 were significant at the 5% confidence interval.

The mean of the yield data from each treatment was also converted to kilograms per hectare basis and used in the calculation of analysis of variance (Table 6). The effect of inoculation level but not inoculation time was significant at both 1% and 5% confidence intervals. In the experiment planted on 29 December 1976, significant yield reduction was obtained (P .05) when 25% or more of the plants were inoculated and (P .01) when 50% or more of the plants were inoculated. For midbloom stage inoculation, significant yield reduction (P .05) was obtained when 75% or more of the plants were inoculated in all three experiments.

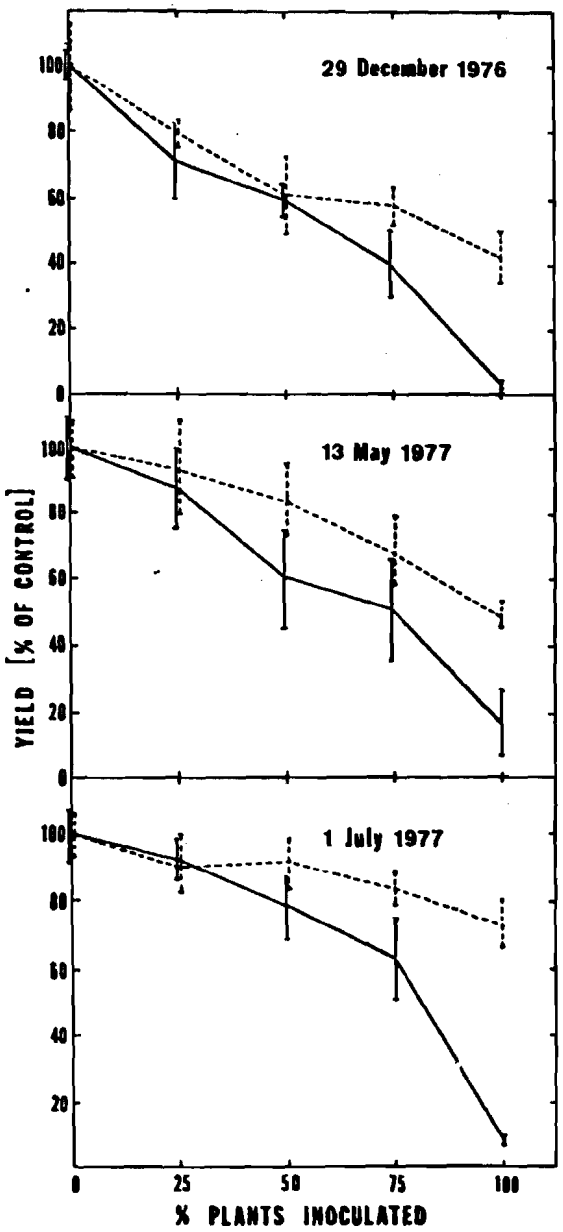


Figure 1. Relationship between yield (expressed as % of noninoculated control) and inoculated levels from three experiments with four replications for experiment planted 29 December 1976 and five replications for the other two experiments. Soybeans were inoculated with the Puerto Rico isolate of cowpea mosaic virus at the primary leaf stage, or midbloom stage. Vertical bars represent one standard deviation range.

Significant yield reduction resulted when 25% of the plants were inoculated with CPMV-PR at the primary leaf stage (Table 10). However, there was no significant difference in any of the experiments between the two inoculation times employed. Midbloom stage inoculation always gave higher yields than primary leaf stage inoculation, although the difference was not statistically significant. The yield differences between inoculation times were greatest when all the plants were inoculated.

The very low yield from 100% inoculation of the primary leaf stage is in agreement with observations in both the field and in the greenhouse that CPMV-PR infected soybeans produce very little if any seed. This is because of the flower bud blight symptoms. However, the yield reductions at other inoculation levels were not proportional to the number of plants inoculated. In the first experiment the slope of the line showing the relationship of percentage yield and inoculation levels was larger (-0.9077) than the slopes measures in the summer experiments (-0.8539 and -0.8532). During the winter months the plants were subjected to shorter days. The amount of vegetative growth under these conditions was less than that achieved in the summer experiments when plants were more apt to perform up to their genetic potential and should be producing more yield to compensate for the infected plants. Caviness and Miner in 1962 found stand reduction of up to 45% at two weeks before bloom had no effect on soybean seed yield. A similar effect was reported with increased spacing within rows of navy beans Phaseolus vulgaris, by Goulden in 1976. As observed in my experiments, CPVM-PR infected soybean plants were stunted and sometimes killed. Thus, infected plants contributed little competition with uninfected plants for light energy and nutrients. This would allow the uninfected soybean plants to exhibit compensative ability and produce more yield than they would have had the infected plants been healthy instead. This would explain the disproportionate yields at 25, 50, and 75% inoculation levels in the summer experiments.

Information on yield reduction due to virus infections is valuable in making decisions about whether control measures, which may be expensive, are warranted. This line of study is needed to gain more insight into the potential threat of virus diseases but is often overlooked. The seriousness of CPMV in cowpeas has been recognized and up to 100% yield reductions have been observed in western Nigeria. However, little was known about the effect of this virus on soybeans. Although my study on the field spread of virus from infected cowpeas to soybeans grown nearby indicated low transmission rate, the possibility still exists that CPMV may become a serious threat in soybean production since, under some circumstances, the natural infection of soybeans by CPMV can occur in subtropical areas. The results suggest that significant yield loss occurs in soybeans when the incidence of infection is above 25%. Such disease incidence might occur in situations where CPMV-infected cowpeas and soybeans are grown close by and when the timing of the two crops encourages migration of the beetle vector from senescing, infected cowpeas to young soybean seedlings.

Table 11. Yields (kg/ha) from soybean plants inoculated with the Puerto Rico isolate of cowpea mosaic virus.

Growth state at inoculation	Mean yield (kg/ha) at inoculation levels (%) shown				
	0	25	50	75	100
Planted 29 December 1976					
Primary	1430.51	954.60	796.42	532.80	29.14
Midbloom	1406.92	1114.16	857.48	808.91	596.62
		$FLSD_{.01}$	489.99		
		$FLSD_{.05}$	295.44		
Planted 13 May 1977					
Primary	1611.22	1420.84	964.59	653.30	275.22
Midbloom	1354.70	1275.21	1152.21	931.86	670.67
		$FLSD_{.01}$	406.44		
		$FLSD_{.05}$	245.07		
Planted 1 July 1977					
Primary	1641.13	1518.36	1283.23	1044.75	128.26
Midbloom	1384.76	1256.84	1272.54	1170.34	1022.71
		$FLSD_{.01}$	216.92		
		$FLSD_{.05}$	130.79		

Recent Publications

Kim, K. S., T. L. Shock, and R. M. Goodman. 1977. Ultrastructural and cytochemical responses in bean leaf cells infected with bean golden yellow mosaic virus. Proc. Amer. Phytopathol. Soc. 4:132.

Goodman, R. M. 1977. Single-stranded DNA genome of a whitefly-transmitted virus of beans. Proc. Amer. Phytopathol. Soc. 4:142.

Bowers, G. R. Jr., and R. M. Goodman. 1977. Seed transmission of soybean mosaic virus. Proc. Amer. Phytopathol. Soc. 4:92.

Goodman, R. M. 1977. Single-stranded DNA genome in a whitefly-transmitted plant virus. Virology 83:171-179.

Goodman, R. M. 1977. Discovery of a new kind of plant virus. Illinois Research 19(3):5.

Thongmeearkom, P., and R. M. Goodman. 1978. Complementation and pseudorecombination between ribonucleic acids from two natural isolates of cowpea mosaic virus (severe subgroup). Virology 85:75-83.

Goodman, R. M., and J. Bird. 1978. Bean golden mosaic virus. OMI/AAB Descriptions of Plant Viruses No. 192. Commonwealth Mycological Institute, Kew, England. (in press).

Paschal, E. H. II, and R. M. Goodman. 1978. A new source of resistance to soybean mosaic virus. Soybean Genetics Newsletter 5:(in press).

Thongmeearkom, P., and R. M. Goodman. 1978. Electrophoretic properties of cowpea mosaic virus (severe subgroup). J. Gen. Virol. (in press).

Goodman, R. M., and S. Ryan. 1978. Soybeans: Meat without bone for a hungry world. Social Policy 8(5):12-15.

Kim, K. S., T. L. Shock, and R. M. Goodman. 1978. Infection of *Phaseolus vulgaris* by bean golden mosaic virus: Ultrastructural aspects. Virology (in press).

APPENDIX III

Report on International Soybean Entomological Research
Michael E. Irwin, Assistant Professor
Agricultural Entomology

I. DEVELOPMENT OF IMPROVED GENETIC MATERIAL FOR USE IN LDC SOYBEAN BREEDING PROGRAMS

A. Breeding program (R. L. Bernard and Kogan): In 1971 a breeding program was initiated to incorporate resistance traits of PI's 171.451 and 229.358 into commercial varieties of soybeans. Although these PI's had been originally selected for resistance to the Mexican bean beetle there is evidence that they also confer resistance to other soybean defoliators such as bean leaf beetles and velvetbean caterpillars, both serious pests of soybean in Latin America.

Crosses were performed by Richard L. Bernard (USDA-ARS, Urbana) and initial screening of progenies was done in the greenhouse. F2 materials were sent to Brasil and Puerto Rico, and a recent note by Paschal and Minor states that some degree of resistance was conferred on *Anticarsia gemmatalis*, the velvetbean caterpillar (Attachment A).

Data from Indiana and Maryland on resistance rating show that resistance was recovered at about 50 percent in some of the best progenies. Given the characteristics of the infestations in some LDC's these levels of resistance, if confirmed by additional field and laboratory tests, should be enough to produce about a 75 percent reduction in insecticide applications against defoliators. This estimate is based on the fact that in most outbreak situations populations are frequently at the border-line of the established economic injury levels. The additional resistance incorporated into these lines may, therefore, tip the equilibrium enough to maintain most populations below that level. These results are preliminary; however, the results are quite encouraging.

II. EXPANSION OF THE KNOWLEDGE BASE IN SOYBEAN PRODUCTION, PROTECTION AND UTILIZATION (Kogan, Irwin, Eastman)

A. Sampling methods for soybean associated arthropods: A book on sampling procedures for soybean arthropods is being prepared with the cooperation of 23 U.S. and foreign specialists. About one half of the chapters have been received and editing will begin soon. There is a tentative agreement with Springer Verlag for publication of the book which should be completed by the end of 1978.

This book will bring to researchers and extension personnel around the world the latest methodology and technology for

sampling soybean arthropods, both pests and beneficial species. It will aid in making estimates of population densities comparable between localities, and it will give a good start to entomologists beginning to work in the field of soybean pest management, no matter where they are located.

III. SOYBEAN DISEASE CONTROL

A. Soybean Mosaic Virus (SMV) Epidemiology (M.E. Irwin, R. M. Goodman, S. E. Halbert, E. A. Allison, T. L. Shock).

Soybean mosaic virus (SMV) occurs wherever soybeans are grown and from a global perspective, is probably the most common and most important virus infecting soybean. The impact of SMV on soybean yield varies depending on locality. It is very important in South Korea, Indonesia, and Ecuador. In small experimental plots we have recently measured yield reductions of over 75% when 100% of 'Williams' soybeans were mechanically inoculated with the Illinois Severe Isolate of SMV 9 days after planting (growth stage VI). In the same experiment we detected reductions of over 30% in seedling emergence from seeds produced by plants inoculated at growth stage VI (Figure 1).

These results strongly suggest that time of inoculation is directly and positively correlated with yield quality and quantity (Figure 1). In fact, if plants are infected at or after bloom (R2 or later), seed transmission incidence is low. Time of infection is critical for field spread and seed transmission in seed lots under conditions in the North Central United States and probably under conditions throughout the world.

Because the amount of field spread differs between growing regions, it is important to isolate the factors responsible for spread. SMV is transmitted from generation to generation through the seed (vertical transmission), and in the field by various species of aphids in a non-persistent manner (horizontal transmission). Two factors stand out as being extremely important in the field spread of SMV based on our experiments (1975-1978) and literature accounts: percentage of the planted seed that is SMV infected, and flight timing and abundance of vector species.

We have initially elected to study the interactions between the virus and its potential vectors, both in the field and laboratory, in Illinois where proper equipment and facilities are available. The types of experiments we are conducting will give us good indications of potential weak links in the field spread process and will enable us to make reasonable judgements about the yield loss thresholds taking into account the virus strain, the soybean variety, the species of aphid vectors and the timing of the interaction of virus, vectors and plant growth stages.

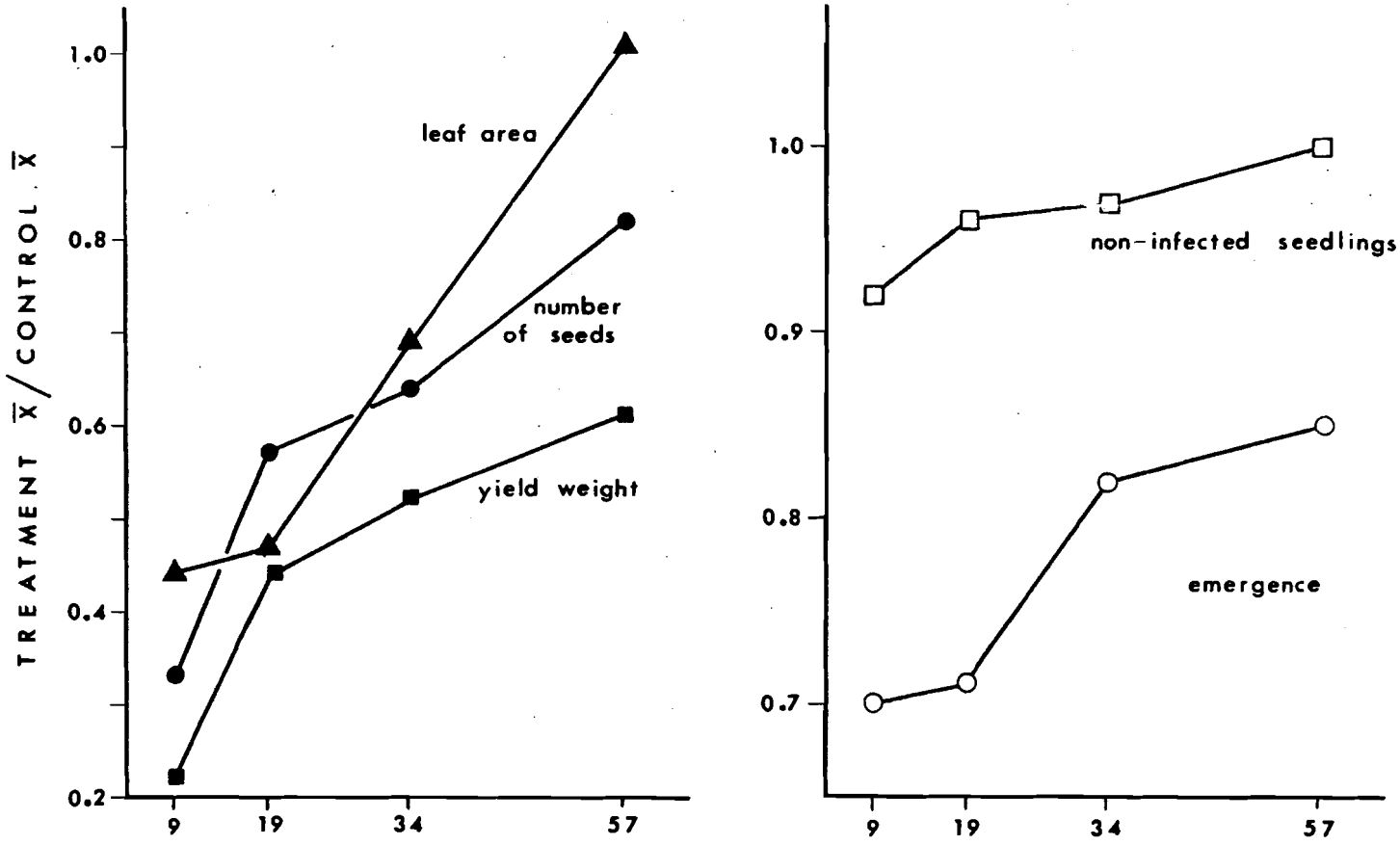


Fig. 1. DAYS BETWEEN PLANTING AND INOCULATION

We have concluded from our studies that there are no important alternate host plants of SMV in central Illinois, and that alternate plants probably play a minimal role as primary inoculum sources in the midwest. We know nothing about this aspect in other areas. Aphids do not colonize soybeans in the U.S. and very rarely do they colonize soybeans in the Western Hemisphere (see below). Thus, the soybean itself is not a factor in the population dynamics of field vectors, at least in the U.S., and probably not in the Western Hemisphere. Some species of aphids do colonize soybeans in Africa and Asia and this added factor must be understood in those areas.

Because SMV is seed transmitted, it is endemic in seed lots everywhere. In the North Central United States infected seeds from one growing season provide the primary inoculum source during the next. The percent of infected seed can, to a large extent, determine the potential for field spread. We estimate the incidence of SMV infection in certified seed lots produced in Illinois is well below 0.01%. Elsewhere in the world, this may be much higher. In one set of experiments, we found infection rates as high as 13% in 'Williams' soybeans mechanically inoculated at stage VI. Seed transmission incidence varies widely with soybean genotype; the highest incidence reported was in 'Midwest' (68%).

Preliminary results from a set of experiments, indicate that the older the plant at time of aphid inoculation, the longer the time interval until the virus can be recovered from the plant. In fact, under field conditions working with our standard tools (Illinois Severe SMV Isolate, 'Williams' soybean, and *Myzus persicae* apterae), the time interval was greater than one month when soybean plants were inoculated by aphids at growth stage R2. Therefore, the time interval for secondary field spread might be great. In large-scale field plots we showed that the major, if not only, spread originated from the primary inoculum source (Figure 2). Preliminary laboratory studies supported these field results.

In preliminary tests, infectivity was recordable by local lesion indexing 6 days after initial inoculation of 'Williams' soybean at growth stage VI. When aphids were used to recover the virus, at least 10 days were required between sap inoculation and recovery. Therefore, SMV in early sap inoculated plants can be detected 4 days before secondary spread by aphid vectors can occur.

Since the effect of inoculation on yield quality and quantity, either by sap or aphid vectors, decreases as the soybean plant develops (Figure 1), time of inoculation is an important factor to consider. This means that the timing of flight activity of potential aphid vectors is critical. At least under the climatic regime of central Illinois, the time period between 10 days after planting and flowering (about 4 weeks) seems most critical for field spread by aphid vectors. We believe that this critical time period is similar under other climatic regimes.

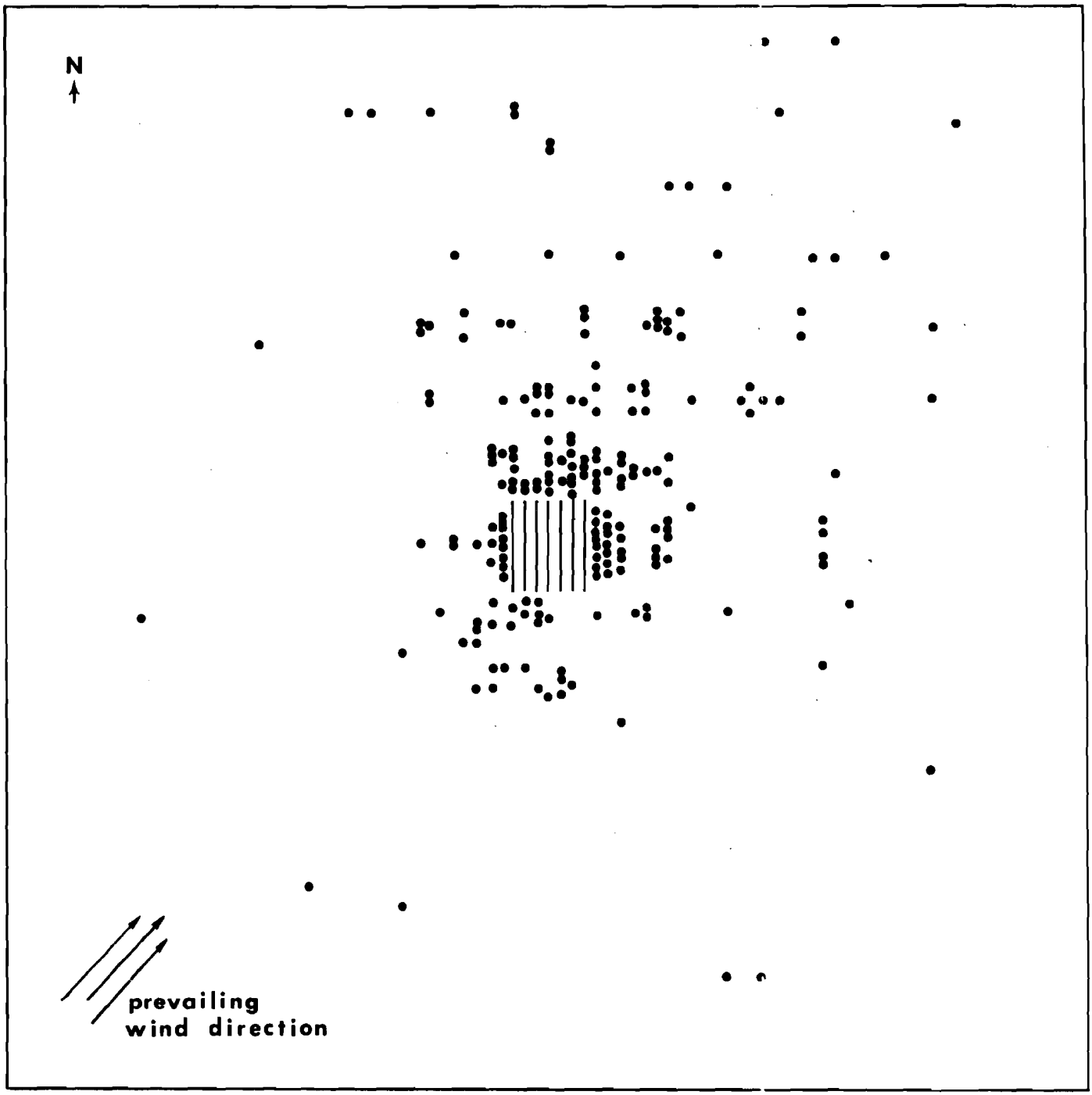


Fig. 2.

Pattern of spread of SMV from primary inoculum source (solid lines in center). Field 300' x 300' Williams soybeans, Urbana, Illinois, 1976.

Continued capture of alate aphids in soybean fields in Illinois produced an interesting picture of the relationship between aphid species, numbers, and their potential to transmit SMV. Over 63 species of aphids have been identified from live trapping with nets within soybean fields in Urbana during the past two seasons (Table 1).

Table 1. Aphid species collecting during live trapping in soybean fields, Urbana, Illinois.

Acyrthosiphon scariolae	Chaitophorus sp.	Myzus persicae
Anoecia corni	Colopha ulmi	Myzus sp.
Anuraphis maidiradiscis	Dactynotus spp.	Nasonovia lactuacae
Aphis armoraciae	Drepanaphis acerifolii	Nasonovia sp.
Aphis asclepiadis	Dysaphis plantaginea	Nearctaphis bakeri
Aphis citricola	Dysaphis tulipae	Nearctaphis crataegifolii
Aphis coreopsidis	Eulachnus rileyi	Pemphiginae (undetermined)
Aphis craccivora	Forda marginata	Periphyllus sp.
Aphis fabae	Hyadaphis erysimi	Rhopalomyzus poae
Aphis gossypii	Hyadaphis foeniculi	Rhopalosiphum maidis
Aphis helianthi	Hyalopterus pruni	Rhopalosiphum nymphaeae
Aphis nerii	Hysteroneura setariae	Rhopalosiphum padi
Aphis rumicis	Macrosiphoniella frigidicola	Rhopalosiphum rufiabdominalis
Aphis sp. Y	Macrosiphoniella ludovicianae	Schizaphis graminum
Aphis spp.	Macrosiphoniella sanborni	Sitomyzus rhois
Aulocorthum solani	Macrosiphum avenae	Therioaphis maculata
Brachycaudus helichrisi	Macrosiphum euphorbiae	Therioaphis rhemi
Brachycolus asparagi	Macrosiphum sp.	Therioaphis trifolii
Calaphis betulella	Myzocallis asclepiadis	Trama rara
Capitophorus elaegni	Myzocallis occulata	
Capitophorus hippophaes	Myzocallis tiliae	
Cavariella nr. hendersoni	Myzocallis walshii	

Of those, some were determined only to genus. Others contain complexes of several species; for instance, the Pemphaginae contain at least 5 species. We estimate that close to 80 species of aphids regularly pass through--and alight on--soybean plants in Urbana. Because aphids are not as diverse in tropical climates, we feel

that the number of aphid species is probably much reduced in the tropics and subtropics. A similar study has been planned to test the hypothesis in Peru and El Salvador.

Of those species collected in soybean fields in Illinois, the following are known SMV vectors (Table 2).

Table 2. Potential SMV vectors collected from soybean fields, Urbana, Illinois.

Vectors cited in literature		Vectors not previously cited	
Field Transmission		Field Transmission	
Successful	Not successful	Many successes	One success
Aphis craccivora	Aphis fabae	Rhopalosiphum padi	Aphis armoracicae
Macrosiphum euphoribae	Aphis gossypii		Aphis citricola
Myzus persicae	Aulocorthum solani		Capitophorus elaegni
Rhopalosiphum maidis	Hyadaphis erysimi		Hysteroneura setariae
			Therioaphis maculata

The most important aphid species found to transmit SMV in the field (Urbana, IL) along with the percentage of transmission successes (=number transmitted/number caught) are tabulated in Table 3.

Table 3. Field transmission by aphid species, Urbana, Illinois 1976

Species	Percent Transmission
Aphis craccivora	18.4
Myzus persicae	15.4
Macrosiphum euphoribae	12.5
Rhopalosiphum maidis	5.7
Rhopalosiphum padi	4.4

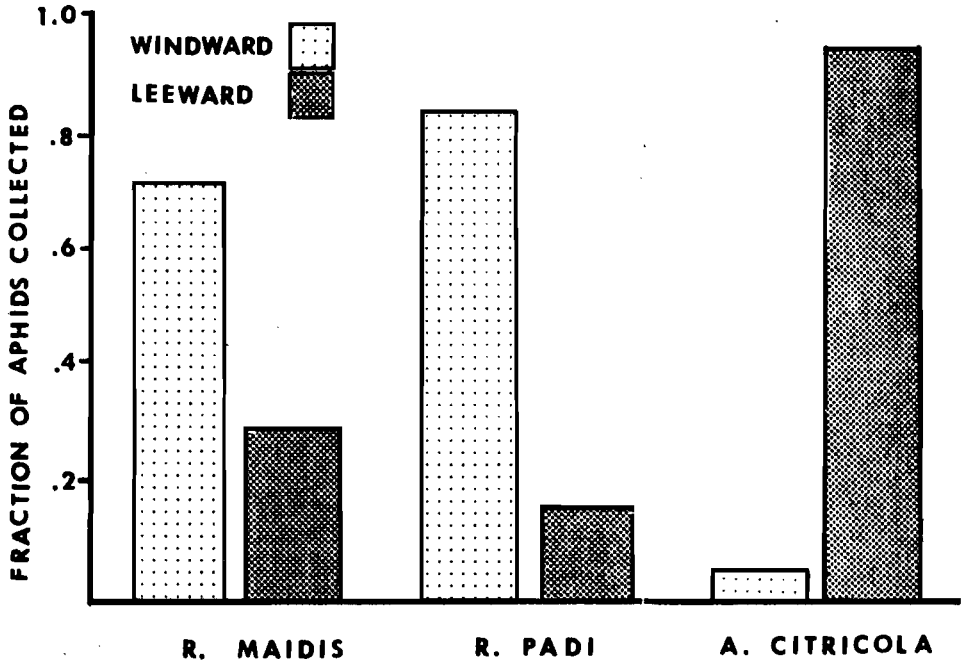
Most of the species of aphids listed in Table 2 and 3 are cosmopolitan, occurring wherever agricultural crops are grown. Although no species of aphids normally colonize soybeans in Urbana, Aphis craccivora occasionally will colonize if soybean plants are stressed. Aphis gossypii colonizes soybeans in Ecuador. A. craccivora, A. glycine and Aulocorthum solani are reported to colonize soybeans in parts of Asia and Africa. Over 65% of all aphids live trapped in Urbana belonged to one or another of the species listed in Table 3. That means nearly two-thirds of the specimens belong to about 6% of the species. By knowing the most important species of vectors, we can concentrate on the flight activity of these, realizing that at least most of the field spread of SMV must be attributed to these few species. There are a couple of other species that could be important in field spread, but we have no information about them. They are Aphis citricola, A. gossypii and Schizaphis graminum. They have all transmitted SMV in the laboratory.

Flight activity patterns from a three year study indicate that certain species tend to fly in the spring (e.g. Aphis craccivora) while others fly in the fall (e.g. Rhopalosiphum maidis). Major flights of these aphid species do not occur at the same times each year, nor are abundances consistent from year to year.

From the standpoint of virus spread, the flight direction of alate aphids can be extremely important. Wind has a strong effect on aphid flight direction. Most species of aphids were collected on the windward side of a sticky trap in two seasons of study. One species, Aphis citricola, was caught predominantly on the leeward side in 1975 (Figure 3). Whether A. citricola actually flies into the wind is not known; it might be so light in weight that it wraps around the collecting container and is carried by eddies onto the lee surface. Further experiments this coming summer should give us more insight into its true behavior.

SMV spread in a large-scale 'Williams' soybean field near Urbana, IL was less during the 1977 season than during the 1976 season. There was a reduction in the number of alatae captured in 1977 over those from 1976, and the seasonal distribution of the aphids did not favor SMV spread in 1977. In 1976, flight activity of aphids was early and spread of SMV was fairly steady (inoculated field) where an inoculum source was present (witness the control field spread) (Figure 4). In 1977 aphid flight activity was very late. The rapid though late rise in virus spread was undoubtedly due to an aphid flight activity peak between 40-60days after soybean planting. Both plots contained SMV inoculum sources, but one also included strips of aluminum to repel flying aphids. Preliminary analysis suggests that this measure was unsuccessful. Figure 5 indicates the flight phenology of aphids capable of transmitting SMV over the past three summers. It is interesting to note that during 1975 most aphids flew during the middle of the summer (mid July-early September), while in 1976 flight activity

Fig. 3 APHID FLIGHT BEHAVIOR WITH RESPECT TO WIND DIRECTION



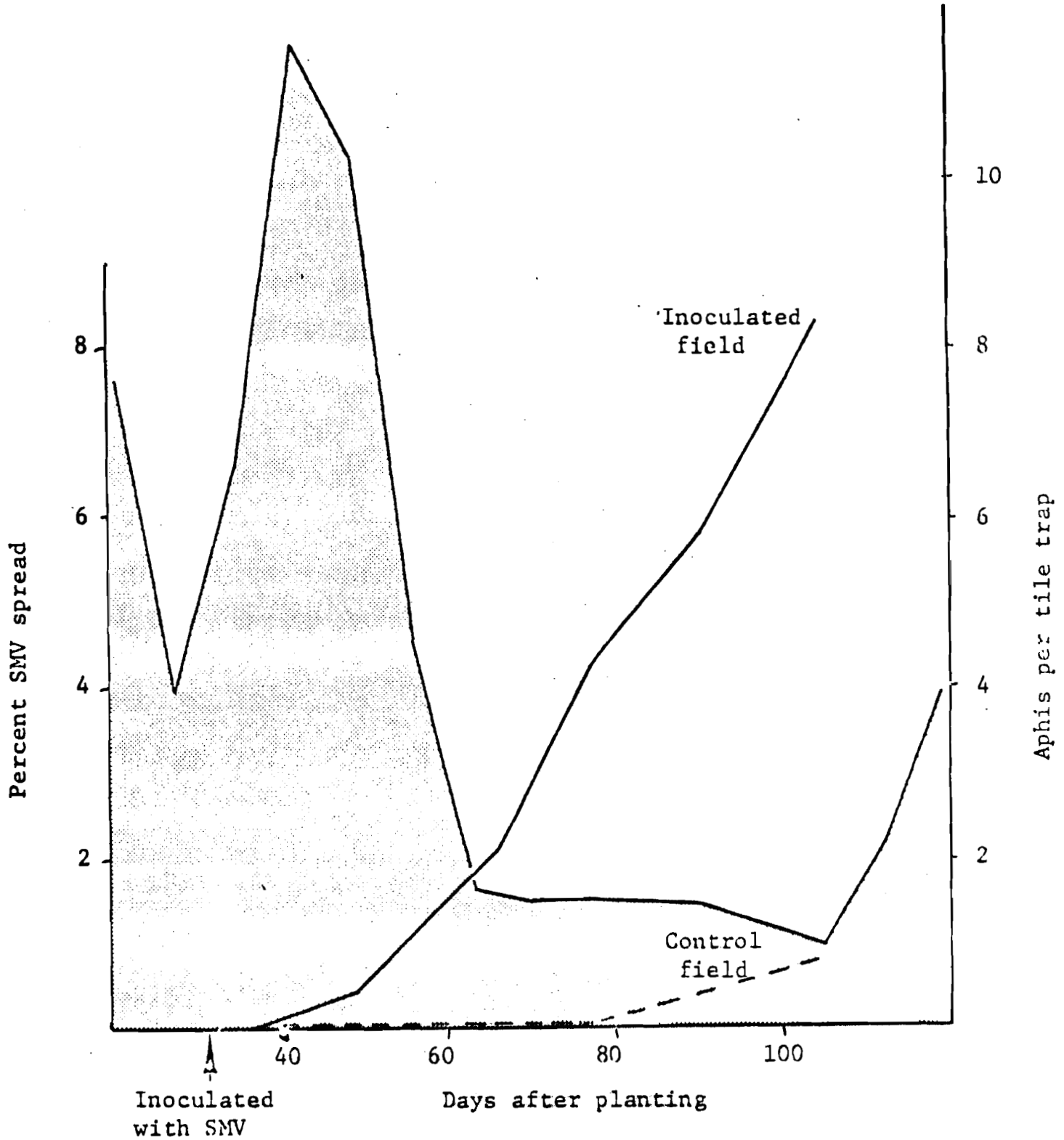


Figure 4.

Field spread of SMV from point source in Tolono, Illinois, 1976

Flight phenology of SMV transmitting aphids, 1976 season.

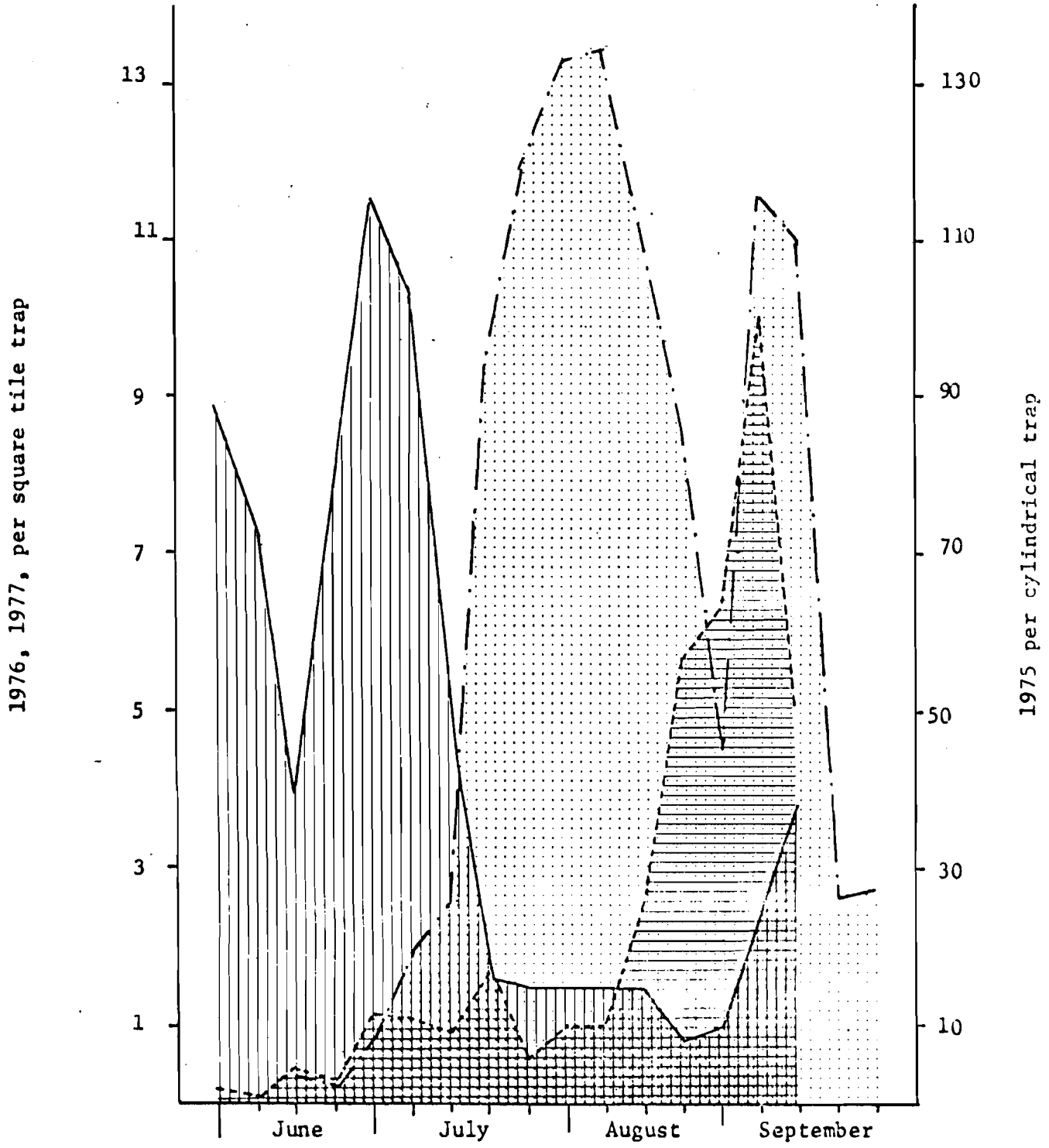


Figure 5. FLIGHT PHENOLOGY AND RELATIVE ABUNDANCE OF SMV-TRANSMITTING APHIDS, TOLONO AND URBANA, ILLINOIS, 1975, 1976, 1977 SEASONS.

BEST AVAILABLE COPY

was early and in 1977 flight activity was late. This indicates that aphid flight activity varies with year. The cause of this shift in activity pattern is not known.

Rhopalosiphum maidis and R. padi were collected in sunflower barriers near soybeans at 1 ft. below canopy, at canopy level, and 1 ft. above canopy level. Nearly 1.7 X more specimens were collected above than below canopy. For Rhopalosiphum spp. barriers may be ineffective in controlling SMV spread because of aphid behavior.

Dark green canopy color attracted 1.4X more aphids than did a light green canopy and the difference was statistically significant ($P < .01$). The numbers of aphids collected in the dark green canopy plot and mixed green plot (plants of dark green and light green approximately 50:50) were not significantly different ($P > 0.1$) for Rhopalosium maidis, but were for all aphids ($P < 0.1$). This indicates that canopy color has an effect on the landing of alate aphids, and that the yellower canopy color is not as attractive as is the darker green color (Figure 6).

IV. DEVELOPMENT OF PEST MANAGEMENT SYSTEMS

A. Bionomics and spatial distribution of soybean-associated thrips (M. E. Irwin; K. V. Yeargan, University of Kentucky; N. Marston, USDA, Columbia, Missouri).

Throughout the world, phytophagous thrips constitute one of the most abundant complexes of arthropods in soybean fields. In an extensive survey of arthropods of Missouri soybeans conducted by Blickenstaff and Huggans in 1962, Sericothrips variabilis (Beach) was 7X more numerous than the second most abundant species, Empoasca fabae (Harris) (Homoptera: Cicadellidae). Two additional species of phytophagous thrips, Frankliniella tritici (Fitch) and F. fusca (Hinds), were among the eight most abundant arthropod species sampled. Together, these three thrips species accounted for more than half of the arthropod specimens caught during the survey. In an intensive arthropod survey of soybeans in the Yagui Valley, Mexico, conducted by Pacheco in 1976, 4.5X more Caliothrips phaseoli (Hood), a phytophagous species, were collected than the second most abundant species, Bemisia tabaci Glennadius (Homoptera: Aleyrodidae). Thrips are known vectors of soybean viruses, and their pest status could increase once the actual relationship between various species of thrips and virus spread is known.

During 1975, densities of Sericothrips variabilis (Beach) (Thysanoptera: Thripidae) were monitored in small field plots of soybeans treated with systemic insecticides; carbofuran in the furrow, carbofuran as an 18 cm band, terbufos as an 18 cm band, and disulfoton as an 18 cm band. Adults and immatures were

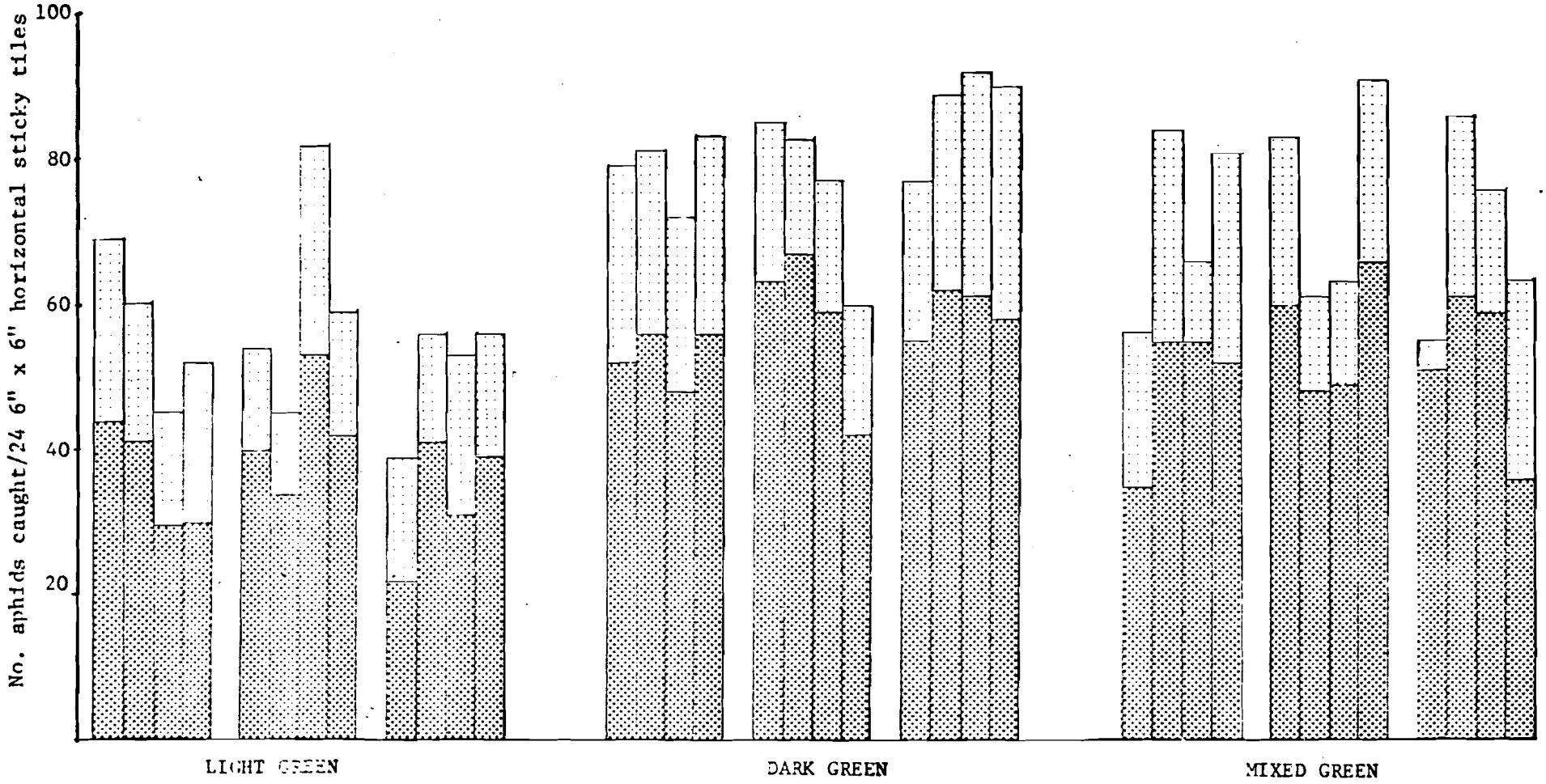


Fig. 6. Total seasonal catch of R. maidis (darker shading) and all other aphids (lighter shading) at trap tiles in canopy color experiment, Veg Crops, Urbana, 1977.

BEST AVAILABLE COPY

tabulated separately. Immature thrips were better indicators of systemic insecticide activity. Although the densities of immature thrips varied between systemic treatments, the main differences were between all systemic treatments and the control. The densities were lower in the systemic treatments for at least one month after initiation of the experiment and for a further week in the disulfoton and terbufos treatments. Although the systemic treatments maintained densities of immature thrips significantly below levels of the controls, a statistically significant yield difference could not be detected. Results are tabulated in Table 4.

During 1976, a joint experiment was conducted on the spatial and temporal distribution of phytophagous thrips in soybeans. Two species of phytophagous thrips, Sericothrips variabilis (Beach) and Frankliniella tritici (Fitch), were found to colonize soybean plants in Urbana, Illinois, Lexington, Kentucky and Columbia, Missouri. Horizontal distribution within fields and among plants did not differ significantly. However, both species were vertically stratified within the soybean canopy. All stages of F. tritici were concentrated in terminal buds and blossoms. Adults of S. Variabilis were found most commonly on the two uppermost fully expanded trifoliolates. Both species occurred in soybean fields throughout the growing season. Populations of F. tritici peaked earlier than those of S. variabilis. Both species of thrips reached peak population levels about a week earlier in Lexington than in Urbana. Also, population densities were generally higher and rates of population buildup and decline were more pronounced at the Kentucky site.

Although damage thresholds have not been established for these thrips species, there are some guidelines that could help determine sampling procedures: 1) there are two critical sites on soybean plants for these colonizing species (terminal buds for F. tritici and fifth from uppermost trifoliolates for S. variabilis immatures); 2) distribution patterns ranged from uniform to aggregated with no detectable relationship between pattern and plant growth stage or thrips density; 3) border rows have an unknown effect on thrips populations; 4) S. variabilis appears to cause greatest damage during the vegetative stages of plant growth (VI-V6). The $\bar{x}$ vs. the ratio of the $S\bar{x}$ over $\bar{x}$ (RV) (Figure 7) allows one to calculate the number of samples needed to achieve a desired level of accuracy for either species. Therefore, when sampling, it is advisable to avoid border rows, but otherwise select plants to be sampled at random. S. variabilis can be sampled by turning over the fifth from uppermost trifoliolate or the lowest trifoliolate, whichever is youngest, and counting the number of immature thrips. F. tritici can be sampled by removing the thrips from the terminal bud and counting them. The number of sampling units can be calculated from Figure 7.

TREATMENT (Application) @ 1.12 kg A.I./ha	IMMATURE THRIPS AND ORIUS				ADULT THRIPS AND ORIUS				YIELD
	June 14 (26)1/	June 19 (31)	June 26 (38)	July 19 (51)	June 14 (26)	June 19 (31)	June 26 (38)	July 9 (51)	Kg/ha
Terbufos 15 G (band)	23±31a2/ (.00)3/	4±2a (.25)	3±3a (.00)	35±21a (.19)	3±21a (.00)	6±4a (.13)	8±3ab (.00)	2±2a (.07)	3914±303a
Disulfoton 15 G (band)	1±1a (.00)	4±4a (.38)	3±2a (.00)	65±22a (.25)	2±2a (.13)	6±1a (.00)	5±3a (.07)	1±1a (.25)	3833±356a
Carbofuran 10 G (band)	22±6a (.00)	17±14a (.44)	14±6c (.50)	51±18a (.13)	9±2c (.13)	8±5a (.00)	4±1a (.32)	2±2a (.07)	3860±343a
Carbofuran 10 G (furrow)	3±7a (.00)	21±11a (.75)	16±3c (.32)	64±24a (.25)	5±1abc (.00)	7±3a (.07)	7±8ab (.13)	2±2a (.13)	3948±128a
Control	169±38b (.38)	39±16b (1.25)	8±3b (.07)	104±6a (.19)	7±2bc (.13)	5±2a (.07)	11±3b (.07)	2±2a (.00)	3766±87a

Table 4. Numbers of *Sericothrips variabilis* per center leaflet of midstem trifoliolates and numbers of *Orius insidiosus* per center leaflet of midstem and upper trifoliolates of 'Williams' soybean, Dixon Springs, IL, 1975. Numbers given have been multiplied by 10.

1/ Days from sowing and systemic insecticide application to sampling.

2/ *S. variabilis* mean ± 1 standard deviation. Numbers cited have been multiplied by 10. Means for thrips followed by the same letter are not significantly different at the .05 level according to Duncan's Multiple Range Test.

3/ *O. insidiosus* mean population levels given in parentheses (). Numbers cited have been multiplied by 10.

BEST AVAILABLE COPY

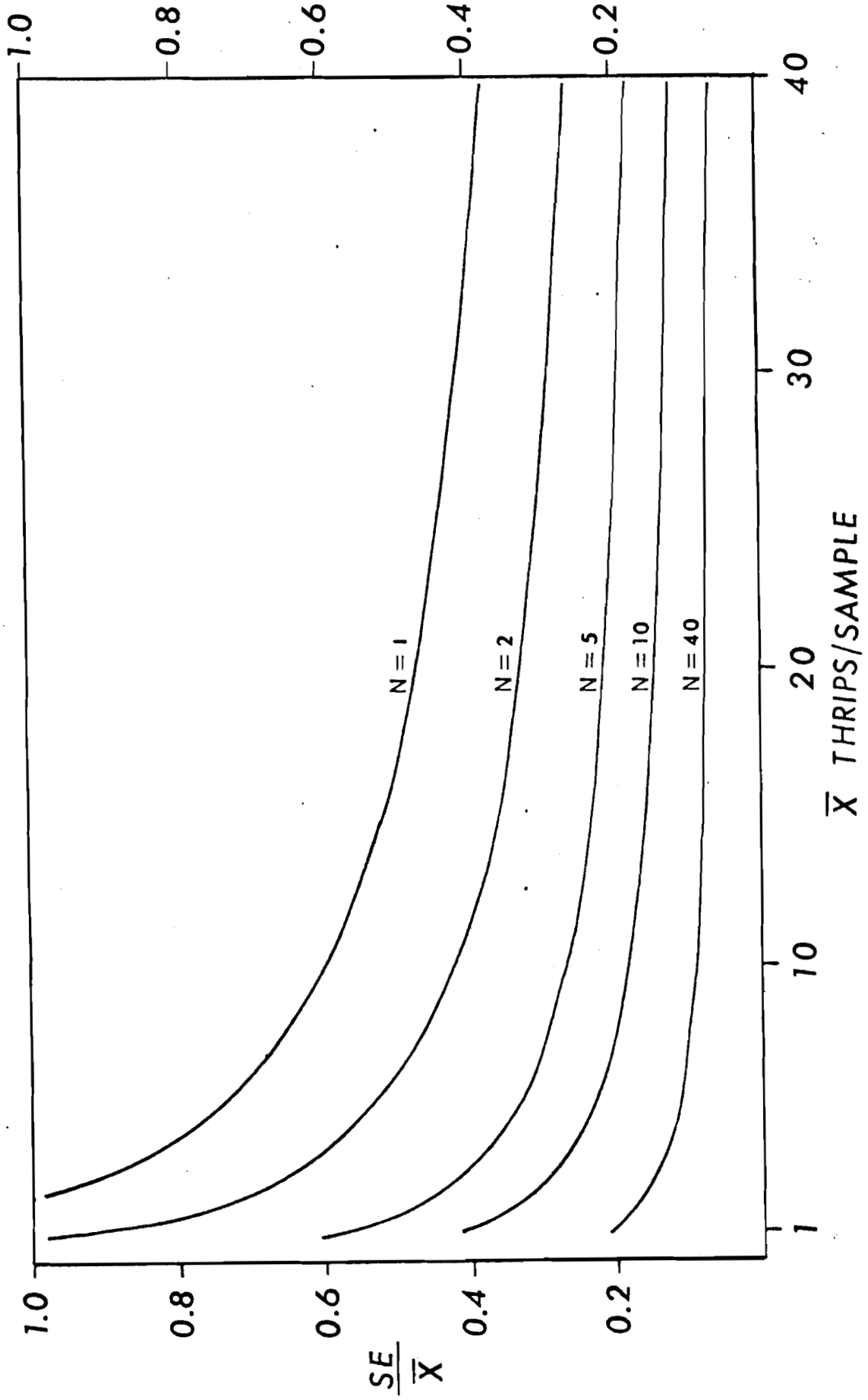


Fig. 7 Relationship between number of samples, thrips per sample, and the accuracy of the estimate of numbers per sample.

B. Orius field dynamics (M. E. Irwin, E. A. Allison): For the past three years field activity of Orius insidiosus has been monitored. Data have not been completely analyzed, but results from wind directed impact trapping indicate that this species tends to fly into the wind, and with a similar but stationary impact trap, prevailing wind had little effect on direction of flight (Table 5). Sex ratios tended to change through the season (1975 and 1977) from more males in the spring to slightly more females in the fall. The 30th or 31st week of the year seemed to be the changeover point both years. Other aspects of Orius flight activity are being analyzed.

Table 5. Number and percent Orius insidiosus collected on four quadrants of two cylindrical impact traps, one stationary (catches from N, E, S, W quadrants), and one wind directed (catches from windward, 90° to windward, leeward, 270° to windward). Urbana, IL, 1975. Prevailing wind from SW.

	Wind Directed Trap				Stationary Trap			
	Windward	90°	Leeward	270°	W	N	E	
Total Orius	185	307	602	336	387	417	376	359
%/trap	13	21	42	23	25	27	24	23

RECENT PUBLICATIONS

Irwin, M. E. 1977. Symposium on the biology and control of major insect pests of Asian soybean. Introduction. Page 165 in R. M. Goodman, ed. Expanding the Use of Soybeans. Proceedings of a Conference for Asia and Oceania. College of Agriculture, University of Illinois, Urbana. INTSOY Series 10.

Irwin, M. E. 1978. Soybean entomology and insect pest management in the USA. In S. R. Singh and Ajibola Taylor, eds., Proceedings of a symposium on insect pests of grain legumes. Ibadan, Nigeria. In press.

Irwin, M. E., and D. E. Kuhlman. 1978. Interactions among Sericothrips variabilis, systemic insecticides and soybean yield. J. Econ. Entomol. Submitted.

Irwin, M. E., and P. W. Price. 1977. Entomophagous insects in a soybean pest control strategy. Pages 108-113 in R. M. Goodman, ed. Expanding the Use of Soybeans. Proceedings of a Conference for Asia and Oceania. College of Agriculture, University of Illinois, Urbana. INTSOY Series 10.

Irwin, M. E., and K. V. Yeargan. In preparation. Sampling thrips in soybean. In M. Kogan and M. E. Irwin, eds., Sampling methods for soybean arthropods.

Kogan, M. 1976. Resistance in soybean to insect pests. Pages 165-169 in R. M. Goodman, ed. Expanding the Use of Soybeans. Proceedings of a Conference for Asia and Oceania. College of Agriculture, University of Illinois, Urbana. INTSOY Series 10.

Kogan, M. 1976. Soybean disease and insect pest management. Pages 114-121 in R. M. Goodman, ed. Expanding the Use of Soybeans. Proceedings of a Conference for Asia and Oceania. College of Agriculture, University of Illinois, Urbana. INTSOY Series 10.

Kogan, M., S. G. Turnipseed, M. Shepard, E. D. de Oliveira, and A. Borgo. 1977. A pilot pest management program for soybean in Southern Brazil. J. Econ. Entomol. 70:659-663.

Mayse, M. A., M. Kogan, and P. W. Price. 1978. Sampling abundances of soybean arthropods: Comparison of methods. J. Econ. Entomol. 71:135-141.

Shepard, M., and M. E. Irwin. In preparation. Sampling predaceous Hemiptera in soybeans. In Kogan, M. and D. Hertzog, eds., Sampling methods for soybean arthropods.

ATTACHMENT A

Anticarsia gemmatalis and resistant cultivars of soybean (Paschal and Minor): The following is a manuscript (minus tables) by E. H. Paschal II and H. C. Minor, INTSOY soybean breeder and agronomist respectively.

Velvetbean Caterpillar Resistance in Soybean Selections From Crosses Involving Mexican Bean Beetle Resistant Plants

Segregating populations arising from crosses involving two sources of Mexican bean beetle (Epilachna varivestis Mulsant) resistance were screened and selected for resistance to velvetbean caterpillar (Anticarsia gemmatalis Hubner) in Guaiba, Rio Grande do Sul, Brasil and Isabela, Puerto Rico. The Mexican bean beetle resistant cultivars used in the crosses were PI 171.451 and PI 229.358 (Van Duyn et al., 1971). The materials tested came from two sources - Dr. R. L. Bernard of the USDA Regional Soybean Laboratory, Urbana, Illinois and Dr. S. G. Turnipseed of Clemson University, Blackville, South Carolina.

The Illinois material consisted of remnant F_2 seed of seven crosses of several midwest varieties and PI 171.451 and PI 229.358. In late 1972 these F_2 populations were planted at Guaiba in single rows bordered on one side by the variety Clark 63 and on the other side by the variety Davis. Plants which exhibited substantially less damage than either Clark 63 or Davis were tagged during the growing season and individually harvested. A total of 66 F_2 plants were selected. Velvetbean caterpillar was the predominant foliage feeder present, and defoliation on both Clark 63 and Davis reached 70%. Progeny of the selected F_2 plants were planted at Guaiba in October, 1973. When seed supply permitted, two 2-m rows of each line were planted; otherwise, only one row was planted. Each row was bordered by Davis on both sides. The lines were visually visually rated for level of defoliation relative to the adjacent rows of Davis, and 150 plants were selected from 38 of the 66 F_3 lines grown.

The South Carolina material was also planted at Guaiba in October, 1973 and consisted of 251 F_5 to F_7 lines which had been previously selected for resistance to Mexican bean beetle. Most of the lines had PI 229.358 in their parentage. In total, 224 individual plants were selected from 112 of the 251 lines.

In October, 1974, the 374 lines (224 from the South Carolina material and 150 from the Illinois material) were planted at Guaiba in a randomized complete block design with two replications. Plots consisted of a single row 2.5 m long bordered on both sides by Davis. The plots were scored four times during the period of peak velvetbean caterpillar attack using the following scale:

Score	Defoliation relative to susceptible check
1	1/16
2	1/8
3	1/4
4	1/2
5	1

Defoliation reached 100% on Davis and most of the lines being evaluated. Four plants of desirable plant type were selected from each of the most resistant lines. These selections were used to continue the Brazilian program. The residual plants in each of the most resistant lines were harvested in bulk, and a portion of this seed was used to initiate the Puerto Rico evaluations.

In February, 1976, the 28 bulks from Brazil were planted at Isabela, Puerto Rico and harvested in bulk. In May, 1977, they were part of a screening of 300 cultivars and lines for resistance to defoliators at Isabela. Plots consisted of 3-m rows bordered on each side by Improved Pelican. A randomized complete block design with two replications was used. A severe infestation of velvetbean caterpillar occurred, and plots were scored on August 2 and 8, using the following scale:

Score	Defoliation relative to susceptible check
1	1/4
2	3/4
3	1

The Improved Pelican border rows, as well as those of susceptible cultivars and lines in the test, suffered 100% defoliation at the time of the second reading (August 8, 1977).

Defoliation scores of selected lines from Brazil and Puerto Rico are presented in Table 1. The results of these screenings indicate that the sources of resistance to Mexican bean beetle also confer some level of resistance to velvetbean caterpillar. A greater number of selected lines had PI 171.451 as a resistant parent than PI 229.358. Although many of the selections are too early for tropical environments, their improved plant type compared to the plant introductions and high level of resistance make them desirable as parents in crosses to develop tropically adapted, velvetbean caterpillar resistant cultivars.

ACKNOWLEDGEMENTS

This report is on research supported in part by the Brazilian Empresa Brasileira de Pesquisa Agropecuaria, the United States Agency for International Development under contracts cm/ta-c-73-19 and grant cm/ta-g-73-49 211(d)

to the International Soybean Program and by the University of Illinois and University of Puerto Rico Agricultural Experiment Stations.

REFERENCE

Van Duyn, J. W., S. G. Turnipseed, and J. D. Maxwell. 1971. Resistance in soybeans to the Mexican bean beetle. I. Source of resistance. Crop Sci. 11:572-573.

APPENDIX IV

Relationship of Variety to Soybean Cooking Quality

A. I. Nelson and L. S. Wei
Professors of Food Science

The search was continued for varieties of soybeans which become the most tender upon cooking. Twenty-seven varieties of soybeans (1976 crop) were tested for tenderness after they were cooked by one of four methods. The objective tenderness of each variety for the last three years was compared to its chemical composition and physical characteristics in a search for factors which correlated with the tenderness of cooked whole soybeans.

Summary

Data from varieties harvested in 1974 and 1975 were reported in the last two years. These experiments were repeated with the 1976 crop in order to test consistency from one crop year to the next. Major factors influencing tenderness were soaking and cooking solutions, soaking or not soaking the beans, and differences due to variety.

1. Composition of soaking and cooking solutions had the greatest effect on objective tenderness of cooked whole soybeans. Use of sodium bicarbonate solutions instead of tap water increased the tenderness of soaked and cooked soybeans by 3.3-fold and cooked but non-soaked beans by 1.7-fold.

2. Soaking before cooking increased tenderness of beans by 2.8-fold when bicarbonate is used by 1.4-fold when plain tap water is used.

3. The tenderness of cooked soybeans varied with variety from 8.0 to 34.3 in case of bicarbonate soak and cook and from 52 to 96 for no-soak and tap water cook.

4. The relative tenderness among varieties varied with soaking and cooking treatment. A given variety was not always more tender than another given variety under all four soaking and cooking conditions. This year, three varieties, Cobb, Ransom and Semmes were among the six most tender varieties in all four treatments.

5. The tenderness of each variety of cooked whole soybeans was not consistent from one crop year to the next over the last three years. Only Cobb soybeans were among the six most tender varieties in all three years.

6. Certain characteristics correlated with the tenderness of the cooked whole soybeans depending on the soaking and cooking treatment used. These characteristics were change in weight after soaking and cooking, change in weight after soaking only, and moisture content.

Methods

Twenty-seven varieties of soybeans from the 1976 crop (Table 1) were soaked and cooked using four methods as outlined in Table 2. Triplicate 100 g samples of mature, whole soybeans were soaked and cooked for studies on amount of water uptake, tenderness and organoleptic qualities. U.S. varieties were supplied by Hank Hill, INTSOY. After soaking, the soybeans were drained and fresh solutions were added for cooking. The soybeans were cooked for sixty minutes and tenderness was determined objectively using a LEE-Kramer shear press and subjectively using a taste panel of five to ten members. Shear press data were analyzed with Duncan's Multiple Range Test and taste panel means were analyzed using randomized complete block analysis of variance.

Twelve physical and chemical measurements were made on each soybean variety in order to find factors which may be used to predict the tenderness of cooked whole soybeans. The physical measurements were: volume/bean (by displacement of water in a sealed flask); weight/bean (average of 300 beans); change in weight after soaking twenty hours in tap water at room temperature, change in weight after a twenty hour soak and sixty minute cooking in boiling tap water; and change in weight after sixty minute cook only. Each variety was analyzed for nitrogen, fat, moisture, fiber, ash and carbohydrate (by difference). Mean values for physical and chemical data were correlated with the varieties' shear press values by regression analysis.

Results

Tenderness (softness) values obtained for cooked samples of each variety of soybean are listed in Table 3. Varieties are listed in order of increasing firmness of soybeans soaked in 0.5% sodium bicarbonate and cooked in 0.5% sodium bicarbonate. It is important to note that the different soak and cook solutions substantially altered the relative position of the varieties with respect to tenderness.

Duncan's Multiple Range Test was used to determine which shear press means were not significantly different. Treatments using bicarbonate over the three test years were used (Tables 4, 5, 6); significant groups varied with the year and treatment. A comparison of shear press tenderness data using a linear regression showed considerable differences. No statistical correlation was found between shear press values for the same variety over the three crop years tested (Table 7).

The four soak and cook treatments (Table 2) resulted in different mean tenderness scores for the cooked whole soybeans; this was also shown

in the two previous reports on 1974 and 1975 crops. Soaking and use of bicarbonate consistently produced more tender beans each year, while tenderness due to variety varied over three years (see Summary #1, a, b and c).

Chemical and physical measurements were made on each variety of soybean (Tables 8 and 9). This year the factors with the best correlation to tenderness were change in weight after soaking (20 hrs tap water); change in weight after soaking cooking (60 minute boil in tap water); and moisture content (Table 10). However, all correlation coefficients were below 0.500 (Table 10). The correlation coefficients varied considerable with each crop. For example: the correlation coefficient for moisture versus tenderness was 0.53 for the 1974 crop, 0.273 for the 1975 crop and 0.063 for the 1976 crop; also the correlation coefficient for density vs. tenderness was 0.542 for the 1975 crop and 0.076 for the 1976 crop. This lack of reproducibility in correlation coefficients from year to year was exhibited in the other factors tested as well.

Each sample was evaluated for flavor, off-flavor and tenderness by taste panelists. Samples were evaluated on a nine-point scale for each of the factors. In case of flavor, 9 indicates pleasing and 1 indicates very poor; in case of off-flavor, 9 indicates its absence and 1 indicates that much is present; in case of texture, 9 indicates very soft, 5 is ideal texture and 1 extremely firm (Tables 11, 12 and 13). A randomized complete block analysis of variance showed that significant differences in the panel results were caused by presence or absence of soaking, the composition of the solution used for soaking and cooking, the variety, the interaction of variety and use of a soak, variety and solution interaction, and solution and use of soak interaction (Table 14).

Table 1. SOYBEAN VARIETIES TESTED AND PRODUCTION AREAS

Variety	State Produced	Variety	State Produced
Amsoy 71	Illinois	Improved Pelican	Louisiana
Beeson	Illinois	Lill	Palmira, Colombia
Bonus	Illinois	Mandarin	Palmira, Colombia
Bossier	Louisiana	Mitchell	Illinois
Calland	Illinois	Ransom	Arkansas
Clark 63	Illinois	Richland	Illinois
Cobb	Alabama	Rillito	Arizona
Columbus	Kansas	Semmes	Arkansas
Corsoy	Illinois	Sri Lanka	Sri Lanka
Davis	Arkansas	Swift	Minnesota
Essex	Tennessee	Tunia	Palmira, Colombia
Forrest	Arkansas	Williams	Illinois
Hill	Arkansas	Woodworth	Illinois
Hodgson	Illinois		

Table 2. EXPERIMENTAL DESIGN FOR SOAKING AND COOKING SOYBEANS

Treatment	Soak Conditions	Cooking Conditions
1	0.5% $NaHCO_3$ in distilled H_2O, 20 hrs room temp.	0.5% $NaHCO_3$ 60 min, 100°C
2	None	0.5% $NaHCO_3$ 60 min, 100°C
3	Tap water[a], 20 hrs, room temp.	Tap water, 60 min, 100°C
4	None	Tap water, 60 min, 100°C

[a] Tap water; partially softened water as supplied by the city of Urbana, Illinois, 80 ppm hardness as Ca^{++}, 80 ppm Na^{+}.

Table 3. EFFECT OF VARIETY, SOAK AND COOK SOLUTION ON TENDERNESS OF COOKED WHOLE SOYBEANS

Variety	Soak	0.5% $NaHCO_3$	None	Tap Water	None
	Cook	0.5% $NaHCO_3$	0.5% $NaHCO_3$	Tap Water	Tap Water
		Mean Shear Press Peak Height (psi)*			
Mitchell		8.0	28.3	48.3	56.0
Ransom		10.0	34.3	40.3	61.7
Cobb		10.7	34.0	42.7	61.0
Rillito		11.0	40.7	55.0	75.7
Semmes		11.0	35.0	43.0	59.0
Columbus		11.3	41.0	43.0	67.3
Hill		11.3	36.0	47.3	69.7
Amsoy 71		12.0	40.3	62.7	78.3
Calland		12.3	40.3	50.7	70.0
Essex		13.3	45.0	50.0	77.0
Mandarin		13.3	49.7	51.0	77.0
Richland		14.0	56.3	45.0	79.7
Lill		14.7	47.0	66.0	62.3
Corsoy		15.0	50.3	60.3	85.3
Bossier		15.0	48.3	48.3	77.3
Tunia		15.3	36.0	30.3	52.7
Woodworth		15.7	49.3	72.0	93.7
Swift		15.7	52.3	54.0	84.0
Williams		15.7	53.7	58.0	91.0
Bonus		16.3	43.0	46.0	72.3
Hodgson		16.7	54.0	54.3	83.7
Beeson		17.3	59.7	70.0	92.3
Forrest		22.3	48.7	70.0	96.3
Sri Lanka		23.0	47.0	74.3	87.7
Clark 63		30.3	64.3	61.7	96.3
Improved Pelican		31.0	39.3	38.7	65.0
Davis		34.3	50.7	53.7	84.3
Treatment Mean		16.2	45.4	53.2	76.2
Treatment Range		26.3	36.0	44.0	43.6

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

Table 4. Significant differences[a] among shear press means as determined by Duncan's Multiple Range Test for 1974 crop soybeans with bicarbonate treatments

20 Hour Soak		No Soak	
Variety	Mean	Variety	Mean
Shakkin Nashi	12.00	Amsoy '71	16.67
Corsoy '73	13.33	Hardee	35.67
Hodgson	14.67	Cobb	37.67
Tracy	14.67	Amsoy	40.00
Colland	15.00	Hodgson	40.33
Bonus	15.00	Bonus	41.00
Woodworth	15.67	Cert. Pelican	42.67
Hark	16.33	Williams	45.00
Cert. Pelican	16.33	Hark	46.00
Wayne	16.33	Semmes	46.67
Williams	16.33	Corsoy '73	48.00
Amsoy '71	16.33	Tracy	48.00
Amsoy	16.67	Hampton	48.33
Clark '63	17.00	Pickett '71	48.67
Corsoy '74	17.33	Wayne	48.67
Swift	18.67	Clark '63	50.00
Hardee	19.00	Calland	50.67
Columbus	19.00	Wells	51.67
Kanrich	19.33	Woodworth	52.33
Semmes	19.67	Kanrich	52.33
Wells	20.33	Columbus	53.00
Beeson	20.67	Forrest	55.33
Hampton	21.00	Swift	56.00
Cobb	25.33	Corsoy '74	59.67
Pickett '71	25.67	Shakkin Nashi	60.00
Forrest	27.33	Davis	61.67
Davis	31.67	Bossier	62.00
Bossier	32.67	Beeson	63.67

[a] Level of significance is 0.05; means connected by a line are not significantly different.

Table 5. Significant differences[a] among variety shear press means as determined by Duncan's Multiple Range Test 1975 crop soybeans with bicarbonate treatments

20 Hour Soak		No Soak	
Variety	Mean	Variety	Mean
Amsoy '71	5.67	Amsoy '71	13.67
Kanrich	6.00	Kanrich	15.00
Hark	6.67	Hark	17.00
Prize '75	6.67	Prize '75	18.67
Bonus	7.33	Williams	21.00
Williams	8.33	Bonus	21.67
Swift	15.67	Cobb	33.67
Steele	16.33	Imp. Pelican	36.67
Imp. Pelican	16.33	Pickett '71	40.33
Ozonoshiki	17.00	Hill	40 67
Woodworth	19.00	Prata	42.33
Hodgson	19.33	Swift	44.33
Pickett '71	20.33	Ozonoshiki	45.33
Planalto	21.00	Planalto	45.67
Ransom	21.67	Steele	47.67
Forrest	21.67	Clark '63	47.67
Cobb	21.67	Columbus	48.00
Perola	22.00	Woodworth	49.67
Davis	22.00	Bragg	51.00
Clark '63	22.00	Corsoy	51.00
Hill	22.33	Hodgson	53.00
Prata	23.67	Bossier	54.33
Columbus	24.00	Forrest	54.67
Essex	24.33	Ransom	56.00
Bragg	26.33	Calland	56.00
Corsoy	27.00	Beeson	56.00
Calland	27.00	Davis	57.33
Bossier	27.00	Essex	57.67
Beeson	28.00	Pampeira	58.00
Pampeira	28.33	Perola	61.67

[a] Level of significance is 0.05; means connected by a line are not significantly different.

Table 6. Significant differences[a] among variety shear press means as determined by Duncan's Multiple Range Test the 1976 crop soybeans with bicarbonate treatments

20 hour soak		No soak	
Variety	Mean	Variety	Mean
Mitchell	8.00	Mitchell	28.33
Ransom	10.00	Cobb	34.00
Cobb	10.67	Ransom	34.33
Rillito	11.00	Semmes	35.00
Semmes	11.00	Hill	36.00
Columbus	11.33	Tunia	36.00
Hill	11.33	Imp. Pelican	39.33
Amsoy '71	12.00	Amsoy '71	40.33
Calland	12.33	Calland	40.33
Essex	13.33	Rillito	40.67
Mandarin	13.33	Columbus	41.00
Richland	14.00	Bonus	43.00
Lill	14.67	Essex	45.00
Bossier	15.00	Lill	47.00
Corsoy	15.00	Sri Lanka	47.00
Tunia	15.33	Bossier	48.33
Woodworth	15.67	Forrest	48.67
Williams	15.67	Woodworth	49.33
Swift	15.67	Mandarin	49.67
Bonus	16.33	Corsoy	50.33
Hodgson	16.67	Davis	50.67
Beeson	17.33	Swift	52.33
Forrest	22.33	Williams	53.67
Sri Lanka	23.00	Hodgson	54.00
Clark '63	30.33	Richland	56.33
Imp. Pelican	31.00	Beeson	59.67
Davis	34.33	Clark '63	64.33

[a] Level of significance is 0.05; means connected by a line are not significantly different.

Table 7. COMPARISON OF TENDERNESS VALUES FOR SOYBEAN VARIETIES FROM THE 1974, 1975 and 1976 CROPS

Variety	Soak/Blanch Solution	Shear Press Value (psi)					
		0.5% $NaHCO_3$			Tap Water		
		1974	1975	1976	1974	1975	1976
Bonus		14.7	15.0	16.3	41.1	45.7	46.0
Calland		14.9	27.0	12.3	52.9	60.6	51.7
Hodgson		14.9	19.1	16.7	40.3	59.7	54.3
Woodworth		15.5	19.1	15.7	56.6	58.8	72.0
Amsoy 71		16.1	11.7	12.0	61.1	43.0	62.7
Hark		16.4	13.7	--	52.3	44.4	--
Williams		16.5	17.0	15.7	59.0	35.5	58.0
Improved Pelican		16.5	16.4	31.0	48.3	46.4	38.7
Clark 63		16.8	21.8	30.3	22.4	50.6	61.7
Corsoy 74		17.3	27.0	15.0	59.1	53.6	60.3
Swift		18.8	15.5	15.7	58.3	48.8	54.0
Columbus		18.9	23.6	11.3	57.3	63.9	43.0
Kanrich		19.7	12.3	--	70.6	36.2	--
Beeson		20.8	27.9	17.3	68.8	64.6	70.0
Cobb		25.5	21.5	10.7	69.1	48.8	42.7
Pickett 71		25.8	20.3	--	63.0	66.7	--
Forrest		27.4	21.5	22.3	75.5	50.0	70.0
Davis		31.9	21.8	34.3	75.2	60.0	53.7
Bossier		32.6	26.7	15.0	77.8	62.7	48.3
Mean 1974 and 1975		20.05	19.94		58.35	52.63	
Std. Dev.		5.74	5.09		13.84	9.51	
r			0.36			0.13	
Mean 1974 and 1976		19.94		18.23	57.68		55.38
Std. Dev.		6.03		7.35	14.68		10.28
r			0.25			0.11	
Mean 1975 and 1976			20.79	18.23		53.29	55.38
Std. Dev.			4.88	7.35		8.50	10.28
r				-0.06			0.05

Table 8. COMPOSITION OF 27 VARIETIES OF RAW, WHOLE SOYBEANS

Variety	Moisture %	Protein %	Oil %	Fiber %	Ash %	NFE* %
Amsoy 71	6.65	39.0	20.7	4.8	4.11	24.74
Beeson	6.99	42.1	20.0	4.6	4.18	22.13
Bonus	8.36	44.2	20.3	4.9	4.48	17.76
Bossier	9.15	42.6	20.8	4.3	4.81	18.34
Calland	8.08	43.7	20.4	4.2	4.46	19.16
Clark 63	7.40	43.9	18.5	4.2	4.53	21.47
Cobb	8.47	38.5	21.6	4.7	4.55	22.18
Columbus	8.32	41.1	21.9	4.5	4.68	19.50
Corsoy	8.94	39.7	22.6	4.6	4.34	19.82
Davis	8.74	39.0	22.9	4.9	4.17	20.29
Essex	10.31	43.0	19.8	4.6	4.27	18.02
Forrest	8.74	38.5	23.0	4.9	4.28	20.58
Hill	9.73	40.3	21.7	4.8	4.48	18.99
Hodgson	6.79	42.8	20.5	4.6	4.70	20.61
Imp. Pelican	8.92	41.0	20.4	4.4	4.47	20.81
Lill	8.10	43.3	19.2	4.4	4.65	20.35
Mandarin	7.16	43.8	20.4	4.5	4.65	19.49
Mitchell	8.47	38.6	22.8	5.0	4.50	20.63
Sri Lanka	10.04	46.2	17.1	5.0	4.28	17.38
Ransom	8.62	35.8	22.5	4.4	4.09	24.59
Richland	7.59	42.5	19.5	4.6	5.00	20.81
Rillito	8.53	38.6	21.6	4.3	4.69	22.28
Semmes	8.81	41.5	20.1	4.5	4.32	20.77
Swift	6.63	41.9	20.2	4.9	4.46	21.91
Tunia	7.70	41.7	21.9	4.7	4.46	19.54
Williams	8.17	34.0	21.5	3.8	4.06	28.47
Woodworth	6.34	40.9	18.3	3.7	4.31	26.45

BEST AVAILABLE COPY

Table 9. PHYSICAL CHARACTERISTICS OF 27 VARIETIES OF WHOLE SOYBEANS

Variety	DRY			% Change in wt with soaking and/or cooking		
	Wt/Bean (grams)	Vol/Bean (cm^3)	Density (g/cm^3)	Soaked[a]	Soaked[b] and Cooked	Cooked[c]
Amsoy 71	.161	.137	1.175	88.50	90.88	81.63
Beeson	.205	.167	1.228	89.77	89.53	79.90
Bonus	.140	.116	1.209	86.66	87.95	80.07
Bossier	.142	.117	1.214	81.34	83.08	74.27
Calland	.182	.151	1.205	91.47	91.81	82.53
Clark 63	.167	.138	1.216	82.64	84.94	77.23
Cobb	.120	.098	1.218	91.05	92.76	82.03
Columbus	.150	.126	1.190	88.32	90.82	77.92
Corsoy	.165	.137	1.202	85.95	84.81	75.37
Davis	.156	.130	1.197	84.60	86.79	77.21
Essex	.133	.109	1.220	82.72	86.30	77.41
Forrest	.146	.123	1.187	85.06	83.91	76.24
Hill	.147	.122	1.206	82.96	85.11	76.23
Hodgson	.169	.141	1.204	80.79	87.01	78.65
Imp. Pelican	.119	.099	1.208	85.02	90.35	81.09
Lill	.179	.151	1.183	83.13	85.73	77.02
Mandarin	.143	.120	1.221	85.07	88.28	77.81
Mitchell	.150	.126	1.190	90.52	92.43	83.54
Sri Lanka	.086	.074	1.162	77.68	78.70	72.47
Ransom	.148	.123	1.199	89.64	92.18	81.89
Richland	.172	.141	1.220	81.07	92.80	82.56
Rillito	.167	.141	1.184	84.89	85.90	77.01
Semmes	.144	.119	1.210	85.38	85.65	75.60
Swift	.170	.142	1.193	86.52	91.09	80.43
Tunia	.197	.169	1.169	84.33	89.48	77.43
Williams	.178	.148	1.205	82.49	86.58	75.10
Woodworth	.145	.121	1.198	88.97	90.47	81.03

[a]Soaked 20 hrs in tap water at room temperature.

[b]Soaked as in (a) and cooked as (c).

[c]Cooked 60 min at 100°C in tap water.

BEST AVAILABLE COPY

Table 10. Significance of factors affecting tenderness

Treatment	Factor	Regression Coefficient(r)	Probability > F[a]
Soaked in tap water Cooked in tap water	Soak and cook[c]	.447	.020
Soaked in $NaHCO_3$ sol'n	Soak[b]	.345	.078
Cooked in $NaHCO_3$ sol'n	Soak and cook	.352	.072
No soak	Soak	.364	.062
Cooked in tap water	Soak and cook	.449	.019
No soak	Soak	.426	.027
Cooked in $NaHCO_3$ sol'n	Moisture content	.373	.056

[a] Significance was determined by linear regression analysis.

[b] Soak: Percent change in weight of variety after 20 hours soak in tap water at room temperature.

[c] Soak and cook: Percent change in weight of variety after soaked as described above, drained, and placed in fresh boiling tap water for 60 minutes.

Table 11. MEAN ORGANOLEPTIC FLAVOR SCORES

Variety	Soak / Blanch	0.5% $NaHCO_3$ / 0.5% $NaHCO_3$	None / 0.5% $NaHCO_3$	Tap Water / Tap Water	None / Tap Water	Overall Mean
Mitchell		4.75	6.35	6.40	6.45	5.99
Williams		5.24	6.24	6.48	6.90	6.22
Imp. Pelican		5.13	5.38	6.38	6.00	5.72
Essex		5.74	6.89	6.53	6.63	6.45
Tunia		5.18	6.00	6.55	6.23	5.99
Cobb		5.84	6.37	6.32	6.84	6.34
Mandarin		4.74	6.00	5.89	6.42	5.76
Richland		5.29	6.38	6.10	5.86	5.91
Hill		4.95	6.29	6.14	6.62	6.00
Calland		6.37	6.42	6.47	6.63	6.47
Swift		5.67	6.39	6.44	6.72	6.31
Amsoy 71		4.94	6.27	6.06	6.39	5.92
Corsoy		5.29	6.24	6.43	7.19	6.29
Rillito		4.91	5.74	6.17	6.91	5.93
Ransom		5.33	5.95	6.33	6.81	6.11
Semmes		4.96	5.74	5.91	6.22	5.71
Woodworth		5.10	6.19	5.90	6.29	5.87
Columbus		5.47	6.68	5.95	6.05	6.04
Hodgson		5.39	6.33	6.56	6.78	6.27
Davis		4.88	6.25	6.19	6.63	5.99
Bonus		5.42	6.32	5.84	6.37	5.99
Bossier		5.26	6.37	6.47	6.63	6.18
Beeson		4.89	6.28	6.39	6.39	5.99
Lill		5.28	5.94	6.17	6.44	5.96
Sri Lanka		4.95	5.42	6.00	5.89	5.57
Forrest		5.85	6.60	5.75	6.65	6.21
Clark		5.15	6.30	5.90	6.40	5.94
	Average	5.26	6.20	6.21	6.49	

Table 12. MEAN ORGANOLEPTIC OFF-FLAVOR SCORES

Variety	Soak / Blanch	0.5% $NaHCO_3$ / 0.5% $NaHCO_3$	None / 0.5% $NaHCO_3$	Tap Water / Tap Water	None / Tap Water	Overall Mean
Mitchell		5.35	6.25	6.30	6.35	6.06
Williams		4.38	5.14	6.14	5.76	5.34
Imp. Pelican		5.44	5.25	6.50	6.25	5.86
Essex		5.05	6.68	6.42	6.21	6.09
Tunia		5.00	5.41	6.23	6.41	5.76
Cobb		5.37	6.11	6.05	6.74	6.07
Mandarin		4.58	5.74	5.53	6.32	5.54
Richland		5.52	6.24	6.52	5.95	6.06
Hill		4.48	5.67	5.33	5.48	5.24
Calland		5.84	6.26	6.37	6.53	6.25
Swift		5.17	5.89	6.22	6.94	6.06
Amsoy 71		4.67	6.50	6.00	6.33	5.88
Corsoy		5.00	5.48	5.52	6.43	5.61
Rillito		4.43	5.48	5.96	6.70	5.64
Ransom		4.95	4.71	5.71	6.24	5.40
Semmes		5.17	5.91	6.13	6.43	5.91
Woodworth		4.81	5.86	6.10	6.67	5.86
Columbus		5.89	6.68	6.05	6.37	6.25
Hodgson		4.50	5.61	6.67	6.67	5.86
Davis		5.38	6.50	6.63	7.25	6.44
Bonus		4.47	6.00	5.95	6.53	5.74
Bossier		4.63	6.26	6.47	6.68	6.01
Beeson		4.22	5.83	6.28	6.94	5.82
Lill		4.66	5.94	6.22	6.33	5.79
Sri Lanka		5.11	5.68	6.05	5.79	5.66
Forrest		5.45	6.40	5.20	6.25	5.83
Clark		4.85	5.90	6.05	6.50	5.83
	Average	4.98	5.90	6.10	6.41	

Table 13. MEAN ORGANOLEPTIC TENDERNESS SCORES

Variety	Soak / Blanch	0.5% $NaHCO_3$ / 0.5% $NaHCO_3$	None / 0.5% $NaHCO_3$	Tap Water / Tap Water	None / Tap Water	Overall Mean
Mitchell		7.45	4.90	4.25	3.95	5.14
Williams		7.10	4.38	4.38	3.38	4.81
Imp. Pelican		7.06	4.88	4.94	3.88	5.19
Essex		7.00	4.37	4.05	3.26	4.67
Tunia		7.00	4.82	5.18	4.32	5.33
Cobb		6.84	4.74	4.32	3.79	4.92
Mandarin		6.84	4.00	4.11	3.05	4.50
Richland		6.71	3.95	4.24	3.52	4.61
Hill		6.67	4.62	4.19	3.19	4.67
Calland		6.63	4.89	4.05	3.37	4.74
Swift		6.61	4.56	4.06	3.61	4.71
Amsoy 71		6.50	4.33	3.94	3.39	4.54
Corsoy		6.48	4.29	3.57	2.67	4.25
Rillito		6.47	4.87	3.96	3.70	4.75
Ransom		6.43	4.81	4.29	3.57	4.78
Semmes		6.39	4.96	4.52	4.00	4.97
Woodworth		6.33	4.29	3.62	2.86	4.28
Columbus		6.26	3.84	4.21	3.32	4.41
Hodgson		6.22	4.33	4.11	3.39	4.51
Davis		6.19	4.00	4.00	2.88	4.27
Bonus		5.95	4.26	4.26	3.21	4.42
Bossier		5.89	4.05	3.79	2.95	4.17
Beeson		5.89	4.11	4.05	3.00	4.26
Lill		5.89	4.11	3.59	2.72	4.08
Sri Lanka		5.79	4.26	3.16	2.84	4.01
Forrest		5.70	4.10	3.00	3.20	4.00
Clark		5.35	3.65	3.60	3.00	3.90
	Average	6.43	4.38	4.05	3.33	

Table 14. Significance of factors affecting organoleptic flavor, off-flavor and tenderness

Factor(s)	Flavor Pr>F[a]	Off-flavor Pr > F[a]	Tenderness Pr > F[a]
Variety	.0009	.0021	.0001
Solution	.0001	.0001	.0001
Soak	.0001	.0001	.0001
Variety - soak interaction	(.9187)	(.8075)	.0022
Variety - Solution interaction	(.2491)	(.1718)	.0022
Solution - soak interaction	.0001	.0001	.0001

[a] Factor is significant where P > F is less than 0.01; parenthesized values are not significant.

APPENDIX V

Report of Work Initiated on Improvement of Technologies for *Rhizobium* Production and Management in Tropical Ecologies

R. Stewart Smith
Assistant Professor, Soil Microbiology

I. Introduction

The INTSOY microbiology position was filled in June, 1977 and research was initiated in Puerto Rico. Initial effort was devoted to the acquisition of office and laboratory supplies and equipment to supplement existing equipment assembled by Dr. Roger E. Smith, microbiologist, University of Puerto Rico, with which the microbiology laboratory is shared, and Dr. Michael A. Ellis, INTSOY seed pathologist, University of Puerto Rico.

The research program initiated during this reporting period largely developed after consideration was given to the objectives of contract AID/ta-c-1294 Output 2, "Improved technologies for *Rhizobium* management in the tropics". However, other reported subjects resulted from specific observations encountered in soybean fields in Puerto Rico.

The major thrust of the research was to better understand the factors affecting *Rhizobia* and soybean nodulation in the tropics.

II. Summary of Research Projects

A. Influence of the rate of soybean emergence on nodulation parameters.

Many factors have been reported to have an influence on the amount of nodulation that develops on soybeans. The more commonly noted soil environmental factors include soil temperature, soil pH, level of soil nitrate, soil dessication, flooding and salinity. Some host influences also play a role in nodulation development including host-strain interactions, general host fertility and other indirect factors altering the host.

This study was initiated to investigate the influence of the rate of early host growth, or seedling vigor, on the amount and location of the resulting nodulation. Seedling vigor, or early rapid growth, was characterized by observing the individual seedling emergence date. This experiment was in cooperation with Dr. Michael A. Ellis, INTSOY seed pathologist, Department of Crop Protection, University of Puerto Rico, Mayaguez, Puerto Rico. Dr. Ellis is funded by grant AID/CM/ta-g-73-50.

Methods

Three experiments are being conducted in this evaluation. A sandbench and field experiment have been completed and a second field experiment is in the final state of data accumulation.

In all experiments a good quality lot of soybean seed was separated into several quantities and placed in an accelerated ageing environment ($40^{o}C$ and 100% relative humidity) for varying lengths of time. A wide variance in seed vigor was obtained by blending seed, from this original seed lot, which had been accelerated aged for 0, 1, 2, 3, and 4 days. The seed was uniformly inoculated with Rhizobium japonicum and planted in either the sandbench or field. Jupiter seed was utilized in the sandbench and first field trial and Jupiter, SJ-1 and Orba in the second field experiment.

Seed vigor treatments were established by tagging plants from the first day of emergence. Successive treatments (number of days to emerge) were established by each day tagging newly emerged plants. After twenty-six days in the sandbench and forty days in the first field experiment, ten plants from each treatment for each of three replications were dug and plant growth and nodulation parameters evaluated. Two harvests were made in the second field experiment. The first harvest was twenty-seven days after emergence, which required sampling each seed emergence treatment in consecutive days. The second harvest was thirty-eight days after planting.

Results

Only the sandbench and first field experiment have been completed and statistically analyzed, therefore, the discussion of this study will not include the last field experiment.

Significant differences in plant and root dry weight were obtained in the sandbench and first field experiment between nearly every adjacent pairs of treatments (Tables 1 and 3). Tables 2 and 4 also show that there is a highly significant negative correlation coefficient between treatment (days to emerge) and these two plant growth parameters. This indicates that increasing number of days to emerge results in a successively smaller plant.

Examination of the number of tap root nodules, total nodules and total nodule weight per plant (Tables 1 and 3) also indicates a significant decrease in these nodulation parameters as the number of days to emerge increases. The range of total nodulation, tap root nodulation and total nodular weight per plant was much larger in the sandbench than in the field experiment. This is most likely due to the poor plant growth which occurred in the field, mainly due to poor soil fertility conditions.

It is important to note that a significant difference in total nodulation occurred in both experiments when comparing the two most vigorous treatments (the first and second date of emergence plants). There were also significant differences in plant weight between these two treatments in both experiments. However, it is anticipated that both of these treatments would be utilized in an evaluation where the number

Table 1. Effect of soybean days to emerge on nodulation and plant growth parameters in sandbench.

Days to Emerge	Plant Weight (g)	Root Weight (g)	Number Tap Nodules	Total Number Nodules	Total Nodule Weight (g)	Weight/ Nodule (g)
4	0.486 A[1/]	0.217 A	16.7 A	30.0 A	0.0177 A	0.0006 A
5	0.412 B	0.186 B	12.5 B	23.2 B	0.0145 A	0.0006 A
6	0.283 C	0.152 C	6.4 C	15.6 C	0.0082 B	0.0005 AB
7	0.194 D	0.106 D	3.7 CD	9.5 D	0.0043 BC	0.0004 BC
8	0.106 DE	0.065 E	1.6 D	5.5 D	0.0021 C	0.0002 C
10	0.067 E	0.049 E	0.4 D	4.0 D	0.0008 C	0.0001 C

1/ Means followed by the same letter are not significantly different at the 5% level.

Table 2. Correlation coefficients from sandbench evaluation of seed vigor on nodulation.

	Plant Weight	Root Weight	Number Tap Nodules	Total Number Nodules	Total Nodule Weight	Weight/ Nodule
Treatment	-0.715**	-0.722**	-0.712**	-0.653**	-0.580**	-0.427**
Plant Weight		0.916**	0.656**	0.774**	0.824**	0.656**
Root Weight			0.653**	0.699**	0.646**	0.541**
Tap Nodules				0.786**	0.637**	0.355**
Total Nodules					0.787**	0.367**
Total Nodule Weight						0.733**

** Significant at the .01 level.

Table 3. Effect of soybean days to emerge on nodulation and plant growth parameters in field conditions.

Days to Emerge	Plant Weight (g)	Root Weight (g)	Number Tap Nodules	Total Nodules	Total Nodule Weight (g)	Weight/ Nodule (g)
5	4.154 A[1/]	0.683 A	4.33 A	16.53 A	0.0135 A	0.0007 A
6	3.358 B	0.566 B	3.33 A	12.97 B	0.0098 AB	0.0008 A
7	2.651 C	0.447 C	3.07 A	11.40 B	0.0106 A	0.0008 A
8	1.585 D	0.286 D	0.87 B	4.50 C	0.0054 B	0.0008 A

1/ Means followed by the same letter are not significantly different in the 5% level.

Table 4. Correlation Coefficients from field evaluation of seed vigor on nodulation.

	Plant Weight	Root Weight	Tap Nodules	Total Nodules	Total Nodule Weight	Weight/ Nodule
Treatment	-0.652**	-0.697**	-0.415**	-0.584**	-0.271*	0.033
Plant Weight		0.969**	0.378**	0.514**	0.394**	0.219*
Root Weight			0.403**	0.533**	0.383**	0.184*
Tap Nodules				0.694**	0.594**	0.325**
Total Nodules					0.728**	0.289**
Total Nodule Weight						0.741**

* - Significant at the .05 level.
** - Significant at the .01 level.

and amount of nodulation is used as a criteria for inoculant or rhizobial excellence. This study suggests that a significant variation is introduced into this type of evaluation by sampling plants which vary in seedling vigor. It would therefore be recommended that only plants of initial uniform growth and vigor be utilized in studies or tests examining rhizobial inoculants, and rhizobial nodulation.

B. Number of Rhizobium japonicum necessary to establish satisfactory nodulation in tropical soils.

One of the more practical problems concerning inoculation of soybeans in LDCs is to determine the minimum number of Rhizobium japonicum bacteria needed to produce acceptable tap root and total nodulation and to obtain maximum seed yield in the tropics. Research in the U.S.A. indicates that several hundred thousand R. japonicum are required for good tap root nodulation of soybeans under field conditions. Such data do not exist for the tropics.

Also, the longevity of R. japonicum in tropical soils under the influence of detrimental environmental factors, such as year around high soil temperature, acid soils, heavy rainfall and possibly submerged soils, is an important question to be determined.

The objectives of this study were to estimate the number of R. japonicum, applied at planting, necessary to establish acceptable nodulation, estimate the yield response due to inoculation and to establish rhizobial population levels in field conditions to allow the initiation of a rhizobial survival and longevity study.

Methods

Jupiter variety of soybeans were planted February 20, 1978 at the Isabela Experimental Substation on a location which had no previous soybean history and was free of R. japonicum. The inoculation treatments, with four replications, included an uninoculated control and nine levels of rhizobial inoculation, ranging from 3.9×10^1 R./cm with 10 fold increases up to 3.9×10^9 R./cm. The lowest level of rhizobia did not form nodules, so was side dressed after 23 days with 100 lb/a N-$(NH_4)_2SO_4$ to provide a positive nitrogen treatment. The 8-0 strain of R. japonicum was received as a frozen liquid concentrate commercial preparation from Agricultural Laboratories, Inc., Columbus, Ohio. The frozen liquid concentrate was thawed immediately before planting, diluted in water to provide the required concentrations, and applied into the seed furrow directly on the seeds. This was accomplished via a gravity flow delivery system, which delivered 21 gal./a. rate of the respective inoculation treatments. The liquid inoculant reservoir was mounted on a Planet Jr. bulk hand planter with the liquid delivery tube fastened to the rear of the seed shoe so that the inoculant flowed directly onto the seeds.

Ten plants from each plot were dug for nodulation and plant growth determinations 25 and 53 days after planting.

Results

Data from the two samplings for nodulation and plant growth parameters have been collected but not statistically analyzed. Seed yield will be obtained later to complete the portion of the study concerned with the number of Rhizobia required to obtain satisfactory nodulation.

The rhizobial longevity portion of the study will begin by planting uninoculated soybeans in all plots of block one approximately five months after harvesting the initial crop. The amount of nodulation obtained from each original plot will be obtained and MPN estimates of the soil R. japonicum population performed. This same procedure will be conducted on blocks 2, 3 and 4 after 1, 2, and 3 years respectively. Repeated evaluations of each block will be performed as necessary to estimate the surviving population of R. japonicum with time.

Even though statistical analysis of the collected nodulation data has not been performed, the raw data will be presented and general comments made concerning nodulation and plant growth (Table 5).

For both harvesting periods the plant and root dry weights were not affected by the rhizobial inoculation rates. With the near total absence of nodulation on treatments receiving up through 3.9×10^2 R./cm and yet equally good plant top and root growth, along with uniform dark green foliage, it appears that ample soil nitrogen was available in this soil to provide sufficient uniform vegetative growth. Whether a nitrogen deficiency will develop in the unnodulated plots during the reproductive growth period, and thus be expressed in seed yield differences, will be determined later. Seed yield differences will be important in determining the adequate level of nodulation to provide sufficient nitrogen for maximum seed yield under these tropical conditions.

Inoculation levels of R. japonicum at 0, 3.9×10^1 and 3.9×10^2 R./cm provided no tap or total nodulation, other than an occasional stray nodule. Therefore, it required 3.9×10^3 R./cm to achieve any nodulation. Each additional log increase in the inoculation rate caused an increase in both tap nodule and total nodule numbers for both sampling periods (Table 5). Thus the highest level of inoculation (3.9×10^9 R./cm which is approximately 1000 times as heavy a rate as a granular soil inoculant) provided the higher number of both tap root and total nodulation. Data from the second sampling indicates that possibly a significant increase in both nodulation parameters occurred at the 3.9×10^8 R./cm rate. Whether this increase in nodule number could supply significantly higher rates of symbiotically fixed nitrogen will be difficult to determine from this study.

An examination of the total nodule dry weight per plant at the second harvest indicates that a large increase occurred at the 3.9×10^5 R./cm rate, after which only the 3.9×10^8 R./cm rate appears to be sizably larger. If this is a significant increase in nodule weight and whether this increase in nodule weight was able to provide more nitrogen may

Table 5. Effect of *Rhizobium japonicum* inoculation rates on nodulation and plant growth.

Rhizobium per cm	Treatment	Plant Dry Wt.		Root Dry Wt.		No. Tap Nodules		Total No. Nod.		Nodule Dry Wt/plant		Wt/Nod	
		1st 1/	2nd 2/	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
		(g)		(g)						(g)		(g)	
Control	A	.445	6.81	.157	1.18	0	0	.1	.2	.0002	.0041	.0004	.0189
3.9×10^{1}	B	.442	7.55	.143	1.18	.1	0	.1	.1	.0002	.0008	.0016	.0041
3.9×10^{2}	C	.441	6.65	.158	1.15	.1	.1	.2	.2	.0004	.0023	.0017	.0048
3.9×10^{3}	D	.442	6.74	.145	1.18	.1	.2	.3	.9	.0002	.0058	.0005	.0105
3.9×10^{4}	E	.490	7.41	.162	1.27	.7	1.4	5.9	2.5	.0013	.0204	.0010	.0086
3.9×10^{5}	F	.423	7.34	.144	1.26	5.1	7.5	9.8	15.9	.0049	.0988	.0005	.0069
3.9×10^{6}	G	.474	6.81	.149	1.11	6.4	8.7	12.5	22.1	.0058	.0818	.0005	.0041
3.9×10^{7}	H	.522	7.91	.161	1.27	8.9	11.7	16.0	29.6	.0068	.0874	.0004	.0036
3.9×10^{8}	I	.428	7.23	.146	1.22	11.5	21.1	18.4	54.9	.0073	.1385	.0004	.0026
3.9×10^{9}	J	.411	5.88	.134	.98	14.9	22.1	19.8	55.5	.0061	.1013	.0003	.0018

1/ - 1st harvest at 25 days after planting.

2/ - 2nd harvest at 53 days after planting.

only be determined by evaluating the seed yield and statistically analyzing all data.

The previously published inverse relationship between the number of nodules per plant and the average weight per nodule is illustrated in the data from the second harvest. Comparing the average weight per nodule only in treatments which provided an increase in nodulation (3.9×10^3 R./cm and larger) it is observed that as the total nodules per plant increased from 0.9 to 55.5, the average dry weight per nodule decreased from .0105 g. to .0018 g.

In summary, the logarithmic increase in the inoculating level of R. japonicum provided an increase in both the number of tap root and total nodules. However, the average nodule dry weight per plant became more steady above the 3.9×10^5 R./cm rate. This is caused by the inverse relationship between the total number of nodules and the average dry weight per nodule. It is hoped that significant increases in seed yield will be achieved with nodulation. This will provide a basis for estimating the rate of R. japonicum required on virgin soybean soil in the tropics to provide a satisfactory supply of symbiotically fixed nitrogen to allow for maximum yields.

C. Collection of Rhizobium japonicum strains.

A collection of Rhizobium japonicum strains was assembled to which will be added as received other strains demonstrating favorable characteristics. Thirty-four strains now in the collection were received from the USDA, Cell Culture and Nitrogen Fixation Laboratory; Ohio State University; Cornell University and Texas A&M University. These strains were originally isolated from India, Brasil, Japan and several states in the United States.

This collection served as the source of Rhizobium japonicum strains for the high temperature tolerance screening trial and will also be used to provide strains for future strain evaluations such as host-strain efficiency evaluations and tolerance in acid pH soils.

D. Screening of Rhizobium japonicum strains for growth at elevated temperatures.

High soil temperature is a characteristic in many areas of the tropics and subtropics which may be a significant detrimental factor to the establishment of Rhizobium japonicum in the seed zone. Without a sufficient quantity of viable rhizobia surviving the time period from introduction into the soil via inoculation until active soybean root elongation, insufficient nodulation may result which could cause a plant nitrogen deficiency and yield loss later in the season.

The influence of high soil temperatures may also play a significant role in determining the length of time the R. japonicum

population can survive (as a free living microorganism) in the field. Once a location has grown successfully nodulated soybeans and established a population of R. japonicum, the rate of decline of this population will be strongly influenced by environmental factors including high soil temperatures.

Methods

Three experiments were conducted with a total of 30 strains of R. japonicum on agar plates to investigate the strains ability to grow at elevated temperatures. The first two experiments provided a preliminary screening from which to select the most temperature tolerant strains for further evaluation in the third experiment.

Each strain of R. japonicum was grown in Yeast Extract Mannital (YEM) broth to obtain a turbid culture from which to inoculate for the temperature study. Each strain was serially diluted in sterile tap water to obtain the following spread plate dilutions on YEM agar for each experiment; experiment one - 10^{-7} and 10^{-8}; experiment two - 10^{-6}, 10^{-7} and 10^{-8}; and experiment three - 10^{-7}, 10^{-8} and 10^{-9}. One agar plate of each strain, for each of the above mentioned dilutions, was placed in the following temperature incubation chambers for each experiment: experiment one - 25°, 30°, 35°, 40° and 45°C; experiment two - 25°, 30°, 35°, 37.5°, 40°, and 45°C; experiment three - 30°, 35°, 36°, 37.5° and 39°C.

For each experiment the strain's ability to grow at a specific temperature was evaluated by observing the following parameters: the number of days required to obtain a visable colony, an estimate of the average colony diameter after 10 days growth, and the number of colonies after 6 days incubation. All plates which did not have visable growth after 7 days incubation at high temperatures were transferred to the 30°C incubator to determine if the previous temperature had been inhibitory or lethal.

All broth cultures were inoculated onto Jupiter soybean seed in a R. japonicum free field at the Isabela substation to verify each strain's ability to form nodules.

Results

The preliminary screening of R. japonicum strains for growth on agar spread plates at various temperatures provided several useful trends (Tables 6).

When comparing the various incubation temperatures utilized R. japonicum strains grew most rapidly and profusely when incubated at 30° C. This is evident by comparing, between temperatures, the number of days required to form a visable colony and also by comparing the colony size. Twelve strains were visable one day sooner at 30°C than at any other incubation temperature, and in only one instance did a colony develop first at a temperature other than 30°C (strain 8-T at 25°C). The most nearly optimum temperature is also indicated by noting that 15 strains obtained a larger colony diameter after 10 days at 30°C and only strain 587 developed a larger colony at a temperature other than 30°C.

The nodulation results for all strains planted at the Isabela substation indicate that strains 530 and 587 from experiment two and strain 531 from experiment three failed to form nodules. These strains were then considered not to be R. japonicum. Effective strains of R. japonicum were re-isolated from the original stock slant for strains 530 and 587 and these effective strains were re-evaluated for temperature in experiment three. This experience illustrates that in all R. japonicum studies it is necessary to verify the nodulating ability of all cultures by planting in controlled conditions with the soybean host.

Transferring of plates, which did not show visable growth after seven days at elevated temperatures, to 30°C did not initiate colony development. This indicates that these elevated temperatures were lethal and were not merely causing a temporary growth inhibition.

The most significant observation from experiments one and two is that strains of R. japonicum vary in their ability to grow at temperatures above optimum. As indicated above, cultures 530 and 587 in experiment two were not effective rhizobia, therefore, their growth at 40°C is not relevant. Of the 24 effective strains evaluated in the preliminary experiments only 9 formed colonies at 35°C and no strain grew at 37.5°C.

All strains that grew at 35°C plus re-isolated cultures of strains 530, 587 and 531 were more closely evaluated for growth at higher temperatures in experiment three (Table 7). The temperature increments above 35°C (36°, 37.5° and 39°C) were narrower in experiment three than in the previous experiments.

An error was found in the 35°C incubation temperature 16 hours after placing the spread plates in the chamber. At that time the temperature was 39°C, and was immediately readjusted to 35°C.

The data (Table 7) for all strains indicated that this chamber thus provided a temperature stress greater than the 37.5°C chamber, but not as severe as the continual 39°C chamber.

All 10 R. japonicum strains in experiment three grew at 37.5°C but no strain was able to grow at 39°C. However, there appear to be differences between these 10 selected strains in their ability to grow at higher temperatures. When comparing the number of colonies that developed at 30°C (used at 100% colony development) with the average percent of colonies forming at 35°, 36° and 37.5°C (Table 7) it is observed that strains varied from 91.1% (strain 587) to 1.7% survival (strain 6). Strain 6 clearly demonstrated the least tolerance to temperatures above 30°C. All other strains in experiment three survived incubation at elevated temperatures with an average from the 35°, 36° and 37.5°C incubation temperatures of greater than 46% of the number of colonies that developed at the 30°C incubation temperature. Table 7 lists the strains in decreasing order of survivability at the three elevated temperatures.

Table 6. Growth of *Rhizobium japonicum* strains at various temperature on YEM agar plates (preliminary screening - Experiments one and two).

R. japonicum strain	25°C			30°C			35°C			37.5°C			40°C			45°C		
	Days to Appear	Colony Size 1/ (mm)	Colony Count 2/ ($x10^7$)	Days to Appear	Colony Size (mm)	Colony Count ($x10^7$)	Days to Appear	Colony Size (mm)	Colony Count ($x10^7$)	Days to Appear	Colony Size (mm)	Colony Count ($x10^7$)	Days to Appear	Colony Size (mm)	Colony Count ($x10^7$)	Days to Appear	Colony Size (mm)	Colony Count ($x10^7$)
6	4	2.5	150	4	3.5	* 3/	5	3.5	4	** 4/	**	**	-	-	-	-	-	-
110	5	1.5	29	4	2.5	33	5	1.5	11	**	**	**	-	-	-	-	-	-
122	5	4.0	11	4	4.0	17	5	3.0	13	**	**	**	-	-	-	-	-	-
123	5	2.5	10	5	3.0	13	- 5/	-	-	**	**	**	-	-	-	-	-	-
125	6	1.0	1	5	2.0	1	-	-	-	**	**	**	-	-	-	-	-	-
126	4	3.5	85	4	4.0	68	5	2.0	59	**	**	**	-	-	-	-	-	-
138	5	4.0	80	4	4.0	10	-	-	-	**	**	**	-	-	-	-	-	-
142	5	3.0	*	4	3.0	50	4	1.5	33	**	**	**	-	-	-	-	-	-
144	-	-	-	5	2.0	1	-	-	-	**	**	**	-	-	-	-	-	-
8-0	4	4.0	38	4	4.5	27	5	2.0	26	**	**	**	-	-	-	-	-	-
8-T	4	3.5	6	5	4.0	2	-	-	-	**	**	**	-	-	-	-	-	-
N-4	4	3.0	66	4	3.0	54	-	-	-	**	**	**	-	-	-	-	-	-
7	4	1.5	39	4	3.0	14	-	-	-	-	-	-	-	-	-	-	-	-
509	4	2.0	30	4	2.0	13	-	-	-	-	-	-	-	-	-	-	-	-
532	5	2.0	1	4	2.5	5	-	-	-	-	-	-	-	-	-	-	-	-
586	4	2.0	25	4	2.5	16	5	2.0	1	-	-	-	-	-	-	-	-	-
587	4	2.0	154	4	2.5	130	4	3.0	60	4	2.0	100	4	2.0	13	-	-	-
596	5	<1	7	4	2.0	17	-	-	-	-	-	-	-	-	-	-	-	-
527	4	1.0	48	3	2.0	53	-	-	-	-	-	-	-	-	-	-	-	-
530	2	2.0	139	2	2.5	62	2	2.5	140	2	2.5	156	2	1.0	160	-	-	-
543	4	1.5	2	3	2.5	1	-	-	-	-	-	-	-	-	-	-	-	-
566	4	1.0	49	3	2.0	45	-	-	-	-	-	-	-	-	-	-	-	-
572	4	1.5	27	3	2.5	17	-	-	-	-	-	-	-	-	-	-	-	-
588	4	2.0	.4	4	1.5	.7	8	<1	.2	-	-	-	-	-	-	-	-	-
589	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
590	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
591	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
597	8	<1	20	3	1.0	22	-	-	-	-	-	-	-	-	-	-	-	-
599	8	1.0	48	3	1.0	23	8	<1	31	-	-	-	-	-	-	-	-	-

1/ Colony size after 10 days.
2/ Number of colonies after 6 days.
3/ Could not obtain a count because of contamination.
4/ Strain not evaluated at this temperature.
5/ No growth occurred.

Table 7. Percent survival of *R. japonicum* strains at elevated temperatures (Experiment three).

R. japonicum strain	Count at 30°C (10^7)	Percent Survival based on 30° count as 100%			Average percent survival from 35° 36° and 37.5°C	Decreasing order of survival
		35°C	36°C	37.5°C		
587	154	74.0	114.9	84.4	91.1	1
599	139	67.6	99.3	81.3	82.7	2
110	33	42.4	--	112.1	77.3	3
530	83	50.6	97.6	66.3	71.5	4
142	193	40.9	90.7	57.0	62.9	5
8-0	142	6.3	88.0	88.0	60.8	6
126	188	23.9	87.2	64.4	58.5	7
122	141	19.1	89.4	46.8	51.8	8
586	151	27.8	71.5	40.4	46.6	9
6	139	0	4.3	0.7	1.7	10

This preliminary screening of R. japonicum strains at high incubation temperatures indicates that there are differences among strains. Further research will be conducted to extend the investigation from agar plate growth to host nodulation at high temperatures with the most temperature tolerant R. japonicum strains.

E. Evaluation of alternate inoculant carriers for the tropics.

The standard carrier for rhizobia in inoculant production throughout the world has been finely ground peat. This material has been used for over forty years and still provides the best suitable material, both from the rhizobial bacteria performance and economic standpoints. This material has been used mainly as a fine moist powder which is seed applied at planting. Recently peat has been formulated as a granular inoculant carrier, which is "soil applied" by delivering the granular into the seed furrow immediately after the seed.

In the development of inoculant practice and production in LDCs other methods of inoculating and alternate carriers will have to be developed because of the general lack of appropriate peat sources in the tropics. Not all peat sources are suitable as an inoculant carrier, therefore, all potential peat materials must be thoroughly tested in association with rhizobia bacteria.

This makes it advisable to investigate alternate sources for use as inoculant carriers, especially from materials which are readily available in the tropics.

It is the objective of this study to evaluate the suitability of a chemically treated and nontreated coconut "coir" dust, along with a semitropical source of muck, and compare them to a commercially available peat source from the U.S.A.

This experiment is in cooperation with Dr. Roger E. Smith, University of Puerto Rico who is being funded by A.I.D. under the 211(d) Biological Nitrogen Fixation program in the Consortium on Soils of the Tropics.

Methods

Four inoculant carriers were selected for evaluation: commercial U.S.A. peat, Florida muck, untreated coconut coir, and NaOH washed (treated) coir. Analysis of acetone extracts from coir showed that they inhibited growth of rhizobia in filter paper disc assay. Thin-layer chromatography of the extracts revealed the presence of both tannins and coumarins. An attempt was made to remove these inhibitors by extracting coir with 5% NaOH (w/v) for one day.

All finely ground carriers were analyzed for physical particle size distribution, pH, organic matter and various moisture retaining parameters (Tables 8 and 9).

Inoculants were prepared with the four carriers using two different cross inoculation groups of rhizobia: R. japonicum - strain 8-0, and cowpea group rhizobia - strain 233 BLR. The inoculants were prepared by mixing the dry carrier, rhizobial culture and lime (if required) in a plastic bag. After mixing and blending, each carrier was subsampled three times for pH, moisture, rhizobial counts and bacterial, actinomycete and fungal contamination counts. Rhizobial estimates were determined by serially diluting and plating on "Vincents" rhizobial agar medium. Plate counts were determined after colony development. The three groups of microbial contaminants were estimated by plating on selective media for each group: bacteria were counted on Nutrient agar; actinomycetes were counted on Benedict's actinomycete agar; and fungi were counted on Potato Dextrose Agar (PDA).

Following the initial smapling, immediately after the inoculant formulation, all materials were sealed in a plastic bag and placed in a 35°C incubation chamber to provide a simulated tropical stress temperature. Periodic sampling for rhizobia counts, bacterial, fungal and actinomycete contamination counts, Ph and moisture determination will be performed to determine the overall performance of each material as a suitable inoculant carrier.

Results

Water Holding Capacity (WHC) for the carriers (Table 8) varied greatly. Both of the organic soil materials were only able to retain approximately 1 to 1½ g. water per g. dry carrier, in comparison to 4.7 and 6.8 g. water for treated and untreated coir respectively. This will allow a much larger quantity of rhizobial culture to be incorporated into a given weight of the coir materials, however, further testing must be performed to determine the optimum moisture content in the coir carriers for rhizobial growth and survival.

Particle size distribution data for the four carriers (Table 9) indicates that the organic soils had a higher percent particle size smaller than the 170 mesh. A fine particle size is advantageous because of an increased moisture absorbing rate and greater ability to adhere to seed when used as a seed applied inoculant.

The organic matter content of the coir carriers was much higher than the organic soils. The initial pH of the peat and untreated coir were below the suitable range for rhizobia so were adjusted with $CaCO_3$. The physical and chemical properties of the coir carrier appears to be satisfactory as a seed applied inoculant, however, rhizobial growth and survival will determine its potential as an inoculant carrier in the tropics.

The initial rhizobial populations of R. japonicum in the four carriers ranged from $3x10^8$ to $9x10^8$ R./g. dry carrier. The initial cowpea rhizobia population ranged from $6x10^7$ to $9x10^8$ R./g. dry carrier.

Table 8. Moisture retaining properties of inoculant carriers.

Carrier	Initial % Moisture	Water Holding Capacity (WHC)			Mixing ratio (ml. Culture/g. carrier)	% Moisture after mixing
		WHC (gH_2O/g)	% Moist at WHC	60% WHC (gH_2O/g)		
Peat	10.2	1.17	57.9	0.70	19.4/50	41.4
Florida muck	20.7	1.47	67.8	0.88	20.6/50	47.9
Coir	7.4	6.83	87.5	4.10	33.3/50	68.0
Treated coir	12.1	4.72	84.6	2.83	33.3/50	68.2

Table 9. Physical and chemical properties of inoculant carriers.

Carrier	Particle Size Distribution (% retained on screen mesh no.)								% Organic matter	Initial pH	Lime adjusted pH
	60	100	140	170	200	230	270	<270			
Peat	0.1	0.2	1.5	50.6	36.3	2.1	0.5	8.7	72.6	5.9	6.8
Florida muck	0.1	3.4	15.2	37.0	25.6	9.2	0.7	8.7	84.7	7.1	7.1
Coir	0.4	36.6	29.9	15.9	6.1	2.4	0.8	7.8	96.2	5.2	7.5
Treated coir	0.2	22.0	26.1	21.7	13.5	6.4	2.1	8.0	95.2	6.8	6.8

Periodic samples have been initiated but insufficient data completed to allow for comments concerning rhizobial population changes during the brief storage period.

Carrier evaluations will continue, via both agar plate counts and host nodulation examinations, until rhizobial counts decrease to a level prohibiting reliable evaluations.

F. Influence of weed competition in soybeans on the establishment of rhizobium nodules.

Field observations of soybean nodulation in existing weed competition trials by Dr. Guillermo Riveros at the Isabela Experimental Substation revealed soybean plants in plots which had not been weeded that were stunted, yellow and poorly nodulated. In plots which had been weeded before the fourth week, the soybeans were tall, green and had much better nodulation.

A follow-up to this observation was made by sampling 10 plants from each of three replications from five weeding treatments and counting the number of tap root and total nodules (Table 10). This indicates that as weeding was delayed until the fourth week or longer the nodulation parameters and plant growth were significantly lower than from plots which were weeded beginning at the first, second, or third week. Dr. Riveros' research conducted under AID grant AID/CM/ta-g-73-50 confirms previous reports that full weed competition during the third to fifth week of soybean growth causes the highest reduction in soybean yield.

To more fully evaluate this effect of weed competition on plant growth and nodulation a cooperative research project with Dr. Riveros, working under the above mentioned AID grant, will be conducted at the Isabela Experiment Substation during summer of 1978.

The experiment will have the objectives of investigating the effects of various weed competition levels on nodulation establishment, determining the yield loss resulting from the absence of nodulation by comparing inoculated vs. uninoculated plots, and comparing possible yield losses resulting from any decrease in nodulation by comparing yields to a plot receiving nitrogen fertilizer.

The experiment will be conducted in a two factorial design with rhizobial inoculation at two levels (inoculated, uninoculated) and weeding at six levels (not weeded, weeding beginning the 1st, 2nd, 3rd, 4th and 5th week). An uninoculated treatment plus nitrogen fertilizer will serve as a positive nitrogen control.

G. Observations of nodule damage by feeding of the bean leaf beetle larvae (Cerotoma).

The literature describes nodule damage by the larvae of *Cerotoma trifurcata* and *Rivellia quadrifasciata*. The larvae stage of these

Table 10. Effects of weed competition on nodulation and plant growth.

Weeks after planting before beginning weeding	No. tap root nodules per plant	Total No. nodules per plant	Nodule dry wt. per plant (g)	Plant dry wt. (g)
1	3.2	53.8	0.70	55.7
2	4.0	57.0	0.81	64.4
3	1.5	23.1	0.63	52.4
4	.83	9.5	0.21	12.7
7	.67	7.3	0.22	6.5

insects feed on the legume nodules leaving only the outer shell of the original nodule with a small hole providing access into the nodule. Little research has been conducted to determine the extent of damage by these insects and their influence on nitrogen fixation and possible yield loss.

While counting the nodules of a soybean - inoculation experiment at the Isabela Experiment Substation the characteristic nodule damage from the nodule feeding insect was observed. In two incidences the larvae was observed protruding from a nodule. This larvae was white in color, except the head and the anal shield, which was almost black. In shape it was subcylindrical, tapering slightly anteriorly, and was very slender. This describes the larvae of the Cerotoma, therefore, this damage will be considered to be due to the bean leaf beetle (Cerotoma).

The extent of nodule damage from the Cerotoma larvae was 32% of the total nodules and 46% of the plants evaluated having at least one damaged nodule (Table 11).

Intentions are hopefully to initiate research on this problem after the University of Puerto Rico acquires an entomologist (currently being selected) to function as the INTSOY entomologist under AID grant CM/ta-g-73-50. Cooperation with the INTSOY entomology staff at the University of Illinois will be encouraged and beneficial.

H. Nitrogen fixation screening with Azospirillum lipoferum and 8 sorghum hybrid lines.

A cooperative project with Dr. Anthony Sotomayor and Dr. Lee Telek of the Mayaguez Institute of Tropical Agriculture (MITA) was conducted at the USDA Research Station at Isabela, Puerto Rico. The objective of this trial was to screen 8 sorghum hybrid lines for effective nitrogen fixation in association with an inoculated strain of Azospirillum lipoferum. This was accomplished by inoculating 8 sorghum lines established in the field with a culture of A. lipoferum and to sample the excised sorghum root in a closed cylinder and to assay via the acetyline reduction method for nitrogen fixation.

Methods

Strain 125 of Azospirillum was obtained from Dr. James Milan, University of Florida and cultured in nitrogen-free "Wisconsin medium". Thirty liters of culture were produced in 6 l. flasks for two separate field inoculations of 285 ml/2 m row. Field treatments consisted of eight sorghum hybrid lines, 4 fertilizer levels (0, 20, 40, 80 lb N/A) and three replications. Within each plot one row was inoculated with the A. lipoferum culture and a control row inoculated only with the Wisconsin medium containing no Azospirillum. Field inoculations were conducted on October 13, 1977, approximately three weeks after planting, and October 31, 1977. The cultures, containing 1.4×10^8 and 1.1×10^8 A. lipoferum/ml respectively, were inoculated onto the

Table 11. Incidence of soybean nodule damage from the larvae of *Cerotoma*.

Row No.	Plants			Nodules		
	Total observed	With damaged nodules	% with damaged nodules	Total observed	No. damaged	% damaged
1	2	0	0	3	0	0
2	10	5	50	55	15	27
3	10	4	40	47	12	26
4	10	9	90	57	37	65
5	6	4	67	25	12	48
6	10	0	0	54	0	0
Total	48	22		241	76	
Average			46%			32%

established sorghum by adding 285 ml of culture/2 m row at the base of the sorghum stalks followed by field irrigation.

Twenty-three days after the second inoculation three plants were removed from both an inoculated and uninoculated plot of hybrid line 5 which had received 40 lb N/A. A Most-Probable-Number (MPN) estimate for A. lipoferum was conducted on root segments to estimate the population of cells within the roots. Segments of roots (0.5 cm) were sterilized for 2.5 minutes in 1% chlorox, washed 5 times in sterile distilled water and crushed in sterile phosphate buffer (pH 7). This extract was serially diluted and inoculated into cotton plugged tubes containing 4 ml of semi-soft Wisconsin agar. After two days incubation at 30°C A. lipoferum was identified as tubes containing a thin pellicle approximately 2-4 mm below the surface, and also by gram staining.

Forty-four days after the second inoculation, attempts were made to recover A. lipoferum from the following plant segments from both Azospirillum inoculated and uninoculated plants: seeds, leaf midrib and stem sections. Similar procedures as described above for root isolations were utilized.

The cooperators sampled excised roots in soil cores and removed them to the laboratory for acetylene reduction assays.

Results

The MPN estimate for A. lipoferum from root segments shows that both the inoculated and noninoculated plants contained appreciable numbers of this organism (Table 12). This would indicate that Azospirillum was abundantly associated with sorghum roots even without inoculation, and that inoculation with A. lipoferum had no effect on the population of this bacterium associated with the sorghum roots. Thirty-two isolates from the MPN tubes have been characterized microscopically and are to be assayed for acetylene reduction capabilities.

Attempts to isolate A. lipoferum from the sorghum seeds, leaf sections and stem sections were unsuccessful because of bacterial and fungal contaminants growing in the N-free soft agar tubes. These nonnitrogen fixing contaminants could grow because of the required nutrients released from the plant tissue segments.

Acetylene reduction assays by the cooperators on the excised root-soil core containers did not reveal detectable ethylene production. None of the 8 sorghum hybrid lines which received two inoculations of A. lipoferum could be detected as having nitrogen fixing capabilities with the system utilized.

Table 12. Recovery of *A. lipoferum* from sorghum roots 23 days after inoculation.

A. lipoferum inoculated	Plant No.	MPN estimate of *A. lipoferum*/g. root
NO	1	3.1×10^5
NO	2	1.0×10^6
NO	3	5.9×10^5
YES	1	3.1×10^5
YES	2	1.8×10^6
YES	3	3.1×10^5

APPENDIX VI

The Soybean Insect Research Information Center (SIRIC)

Jenny Kogan
Research Assistant, Economic Entomology Section,
Illinois Natural History Survey

The Soybean Insect Research Information Center (SIRIC) is a computerized information storage and retrieval system for the world-wide literature of arthropods associated with soybeans. SIRIC is primarily a researcher service-oriented unit, operating in close cooperation with the Soybean Entomology Research Team of the Illinois Natural History Survey and the University of Illinois.

The main objectives of the center are periodically reassessed in response to changing information needs of researchers.

Basically these objectives are:

1. To compile the literature of soybean related arthropods and to establish a data bank for this literature.

2. To organize a collection of relevant documents using codeword descriptors for ready retrieval by means of computerized searches.

3. To help soybean researchers with their information needs.

These goals have been fully accomplished during 1977. New procedures in the input operations allow for more efficient and accurate loading of bibliographic data in the magnetic tapes due to a preliminary proof reading of the input data. In December 1977, SIRIC files contained 16,200 citations, representing an increase of approximately 4,000 citations over the previous year.

During the time covered by this report, 122 requests for service were filled in the form of computer printouts, manual compilations, copies of documents, and referral services. Requests outside the scope of SIRIC were routed to the proper institution or specialist. Requests for copies of documents have to conform with the new U.S. Copyright Law (Title 17, United States Code) in effect since January 1, 1978.

Fifty-three percent (65) of all requests for information or services came from researchers at the University of Illinois or their graduate students. The remaining forty-seven percent (57) were received from individuals in other institutions in the United States and abroad.

SIRIC performed comprehensive bibliographic searches used in the production of review articles and special reports. A survey of the literature on Plant Resistance-Chemical Factors published in the last 20 years was

done in support of Dr. M. Kogan's studies in this field. A search of the literature of insect nutrition was done in support of Dr. J. P. Parra, a post-doctoral researcher from Brasil working with Dr. M. Kogan.

In a recent computer search in response to a request for the literature on insects damaging soybeans, over 1,000 citations were found to be relavant. Printouts were sent to cooperators in Korea, Brasil and Honduras.

In May of 1977, a display on the scope and services offered by SIRIC was prepared for the INTSOY Network Conference. Bibliographies and the brochure "What Is SIRIC?" were distributed among the participants.

Key soybean insects are also important pests of corn, alfalfa, and other crops. For this reason SIRIC has been able to answer international requests for information coming from researchers working with crops other than soybeans. Recent requests for assistance to researchers abroad are listed in Attachment I.

Bibliographies compiled and published within the framework of SIRIC have an importance that exceeds their value as mere guides to the literature of selected insect species. Following the four bibliographies published so far on the Literature of Arthropods Associated with Soybeans, SIRIC is working on the production of a fifth bibliography of two Heliothis species (Heliothis zea and Heliothis virescens). These are considered the number one agricultural pests in the United States and the rest of the New World. Because of their importance much fundamental research on ecology, physiology, genetics and behavior has been conducted using these species as laboratory subjects. The bibliography should have great interest to soybean researchers as well as to those interested in pest management in general. Compilation of papers to be included in the bibliography was completed through December 1977, the cutoff date for inclusion. Final production will involve the editing of the printouts, reassignment of key words, and production of the index. Parts of the sorting procedures will be computerized. The bibliography will contain about 5,850 citations. The outline of the final publication and the organization of the subject index is presented in Attachment II. This bibliography will be published in the INTSOY Publication Series in the 1978-79 contract year.

Recent visitors to the Center include officials and researchers from institutions in Brasil, Colombia, Costa Rica, Korea, Philippines, Sri Lanka and Taiwan.

SIRIC has an operating staff of one librarian working in close cooperation with the Soybean Entomology Team of the Illinois Natural History Survey and the University of Illinois.

A part-time computer programmer and two students of the University of Illinois Graduate School of Library Science give the Center the assistance necessary to operate and maintain the system.

ATTACHMENT I

ARGENTINA

E. Willink
Estacion Experimental Agricola
Tacuman, Argentina

Request: 1. Copies of bibliographies published by SIRIC
2. Computer search on rearing methods for lepidopterous larvae.

BRASIL

G. L. Tonet
CNPT -- EMBRAPA
Passo Fundo, Brasil

Request: Publications on soybean insects

R. Fenilli
CNPGC -- EMBRAPA
Campo Grande, Brasil

Request: Computer searches on soybean insects.

M. da C. Oliveira
CNPS -- EMBRAPA
Londrina, Brasil

Request: Copies of bibliographies published by SIRIC

A. Panizzi
CNPS -- EMBRAPA
Londrina, Brasil

Request: Computer searches on: 1. Hedylepta indicata and 2. Row spacing in soybean plantings and damage caused by insects.

B. Correa
CNPS -- EMBRAPA
Londrina, Brasil

Request: Computer searches on: 1. Epinotia aporema; 2. Insects damaging soybeans.

I. C. Corso
CNPS -- EMBRAPA
Londrina, Brasil

Request: Computer searches on: 1. Biological control of P. includens; 2. Pathogens of A. gemmatalis.

R. F. Pires da Silva
Universidade Federal do Rio Grande do Sul - Faculdade de Agronomia
Porto Alegre, Brasil

Request: Copies of the bibliographies published by SIRIC.

Mercedes M. Panizzi
CNPS -- EMBRAPA
Londrina, Brasil

Request: Copies of papers and information on soybean germplasm collections.

F. Luccini
CNPT -- EMBRAPA
Passo Fundo, Brasil

Request: Copies of bibliographies published by SIRIC and computer searches on: 1. Laspeyresia fabivora; 2. Piezodorus guildinii; 3. Plusia spp.

D. Gazzoni
CNPS -- EMBRAPA
Londrina, Brasil

Request: Computer searches on: 1. Different methods of control of soybean insects; 2. Simulated damage; 3. Soybean plant resistance; 4. Insecticide residues; 5. Life history and habits of Anticarsia gemmatalis, Elasmopalpus lignosellus, Nezara viridula, and Pseudoplusia includens.

COLOMBIA

G. Hallman
ICA
Espinal, Tolina -- Colombia

Request: Computer searches on: 1. Population dynamics of Heliothis spp.; 2. Ecology of Heliothis spp.; 3. Heliothis tergemina; 4. Cardiochiles nigriceps parasitizing Heliothis virescens; 5. Taxonomy of Heliothis spp.; 6. Epinotia aporema; 7. Piezodorus guildinii damaging soybeans; 8. Copies of selected papers.

T. Martinez
Cassava Doc. Center -- CIAT
Palmira, Colombia

Request: Copies of bibliographies published by SIRIC.

DOMINICAN REPUBLIC

P. E. Paz
Instituto Interamericano de Ciencias Agricolas de la OEA
Santo Domingo, Dominican Republic

Request: Computer search on insects damaging soybeans.

ECUADOR

M. de Lopes
INIAP
Guayaquil, Ecuador

Request: Copies of bibliographies published by SIRIC

ENGLAND

D. B. Gerard
Edinburgh School of Agriculture
Edinburgh, England

Request: Computer search on chemical control of tropical legumes

GERMANY

S. Hoffmann
Dept. of Virology -- Rheinischen Friedrich-Wilhems Universitat
Bonn, Germany

Request: Computer search on Bemisia tabaci.

GUAM

L. M. Stevens
College of Agriculture -- University of Guam
Agana, Guam

Request: Copies of bibliographies published by SIRIC.

HONDURAS

H. N. Howell, Jr.
Escuela Agricola Panamericana
Tegucigalpa, Honduras

Request: 1. Computer search on the biology of Spodoptera frugiperda a pest of corn and beans in Honduras; 2. Xerox copies of papers dealing with the subject.

J. T. Ordenez
Secretaria de Estado en el Despacho de Recursos Naturales
Zona Centro Oriental, Honduras

Request: Copies of selected, illustrated papers dealing with soybean pests in Central and South America, published in Spanish.

INDIA

N. P. Kashyap
Dept. of Entomology-Zoology, College of Agriculture
Palampur, India

Request: Copies of bibliographies published by SIRIC.

ISRAEL

D. Gerling
Dept. of Zoology -- Tel Aviv University
Israel

Request: Computer search on parasitoids and predators of Heliothis spp.

THE NETHERLANDS

H. C. Molster
Centre for Agricultural Publishing and Documentation
Wagenigen, The Netherlands

Request: Literature search on *Maruca* spp.

NICARAGUA

R. Daxl
FAO Ecologist Officer
Project Integrated Pest Control
Manuagua, Nicaragua

Request: 1. Computer searches on mechanical control of *Spodoptera frugiperda*; 2. Copies of the bibliographies published by SIRIC; 3. Copies of articles dealing with *S. frugiperda*.

PHILIPPINES

J. A. Litsinger
The International Rice Research Institute
Manila, Philippines

Request: 1. Computer search on the biology and chemical control of *Etiella*, a pod borer of soybeans in the Philippines and Indonesia; 2. Xerox copies of papers dealing with soybean insects.

R. A. Grande
Twin Rivers Research Center
Davao City, Philippines

Request: Copies of bibliographies published by SIRIC.

R. S. Rejesus
Dept. of Entomology -- University of the Philippines at Los Banos
Laguna, Philippines

Request: Computer search on pest management of soybeans.

SURINAM

P. A. Segeren
Dept. of Entomology -- Agricultural Experiment Station
Paramaribo, Surinam

Request: Copies of selected documents and bibliographies published by SIRIC.

THAILAND

Banpot Napompeth
National Biological Control Research Center
Bangkok, Thailand

Request: Publications dealing with soybeans in general.

TRINIDAD

F. D. Bemett
Commonwealth Institute of Biological Control
Trinidad, West Indies

Request: Copies of bibliographies published by SIRIC.

ATTACHMENT II

A BIBLIOGRAPHY OF HELIOTHIS ZEA (BODDIE)
AND H. VIRESCENS (F.)

I. Introduction: Including summaries on the economic importance of the species: taxonomic status; distribution; and host ranges. Criteria for inclusion of papers in the bibliography and the search strategy will be discussed. Examples of major problems encountered in the surveys will be presented.

II. Main body of the bibliography: About 5,200 full citations each followed by the codewords that best describe their contents.

III. Appendix I: List of experiment station annual reports (about 600 citations) - listed only by date of publication and volume and page numbers.

IV. Appendix II: Papers cited in the "Bibliography of American Economic Entomology" and in the "Index to the Literature of American Economic Entomology" that could not be located in the USA or in Canada. Incomplete citations not verified will be listed as they appear in these reference sources (about 50 citations). (The University of Illinois Interlibrary Loan Service is still working on some of these citations and we may still be able to include them in the main body of the bibliography.)

V. Appendix III: List of abbreviations of journals and periodicals used in the bibliography.

VI. Subject index: With separate list for major host crops (cotton, corn, soybean, tobacco, vegetable, and ornamental crops), and key codewords.

Distribution maps will be included.

The following is the proposed structure of the subject index with a list of key words selected for use in preparation of the index.

SUBJECT INDEX

Structure of this index was patterned after the "Thesaurus of Entomology," R. H. Foote, 1977 (Entomol. Soc. Amer. Pub., Washington, D.C., 188p.) and our own Hierarchical Code Descriptors (SIRIC-1974-unpublished). Subject words and their sequences were rearranged in a fashion that represents a compromise between our current retrieval limitations and what we feel should be a detailed subject index for a bibliography of this size.

THE INSECTS

I. External Anatomy, Morphology. No specific codes are used below the general heading. Under this subject matter are included only papers dealing with descriptions of structures that are not merely of a taxonomic diagnostic nature. (All tagmata, internal and external, and sensorial apparata).

II. Systematics, Taxonomy, Nomenclature. Includes evolution and speciation, synonymic lists, diagnostic descriptions, checklists, identification, and catalogues.

III. Life History and Habits. Includes both field and laboratory studies on the life cycle, phenology, and related phenomena. Related terms in this category: life cycle, biology, growth and development, reproduction, oviposition, biological rhythms.

IV. Physiology and Biochemistry. Emphasis in function and biological processes at the organismic and suborganismic level. Includes also histology, cytology, nutrition, nervous system, sensory physiology, olfaction, vision, touch, physiological processes - egg development, mechanisms of oviposition control, etc.

V. Toxicology. Refers strictly to studies on the metabolic effects and mode of action of pesticides (LD 50's).

VI. Insect Pathology. Studies of the pathogens or pathological reaction of the host. Effect of diseases on populations should be coded under biological control - pathogens.

VII. Genetics. (For Population Genetics see Population Studies.)

VIII. Behavior. Includes:

Communication, courtship, feeding behavior, feeding stimulants, host selection, host preferences, oviposition behavior (choice of ovip. sites, etc.), sex pheromones, and sexual behavior.

IX. Ecology. Under this subject matter are included papers dealing with the effect of physical environmental factors on growth, development, survival, etc. of the species. Effects of biotic agents are listed under Population Studies, or Biological Control.

X. Population Studies. Includes population dynamics, population genetics, life tables, modeling, seasonal abundance.

XI. Host Records and Geographic Distribution. Includes host plant range, range of distribution, etc.

XII. Methods. Includes three subcodes:

rearing - diets, sampling, and others.

XIII. Plant Disease. Includes all plant disorders

PROTECTION AGAINST ARTHROPODS

Control Methods

I. Biological Control

Parasitoids
Pathogens (includes microbial control)
Predators

Crops: Corn, cotton, ornamentals, soybean, tobacco, vegetable crops, and others.

II. Chemical Control

Pre-1940, 1940-1960, Post-1960

a. Insecticide evaluation
Pre-1940, 1940-1960, Post-1960

b. Insecticide resistance
Pre-1940, 1940-1960, Post-1960

Crops: Corn, cotton, etc. ...

c. Growth regulators (includes hormonal control, hormore analogues, etc.)

III. Plant Resistance

Crop: Corn, cotton, etc. ...

IV. Cultural Control

Crop: Corn, cotton, etc. ...

V. Mechanical Control

Crop: Corn, cotton, etc. ...

VI. Genetic Control (includes chemosterilants; sterilization).

VII. Pest Management

Economic thresholds/economic injury levels (includes crop loss assessments); scouting and sampling; forecasting/prediction/modeling.

Crops: Corn, cotton, etc. ...

VIII. Regulatory Control (includes quarantines).

IX. Economics (yields/losses/costs)

APPENDIX VII

The International Reference Collection of Soybean-associated Arthropods (IRCSA)

John Bouseman
Assistant Entomologist, Economic Entomology Section
Illinois Natural History Survey

The International Reference Collection, a joint project of the Illinois Natural History Survey and the University of Illinois, currently houses about 110,000 identified specimens of soybean-associated arthropods in over 2,300 taxa. Incremental support is provided by the International Soybean Program, INTSOY, to strengthen the international dimension of the collection and make it more useful to soybean workers outside of the United States. The IRCSA specimens have been received from 23 soybean producing states in the United States and from 35 foreign countries. The major foreign accessions have been from Latin America, with Brasil, Colombia and Mexico especially well represented.

The identified material in the collection is housed in about 200 United States National Museum drawers and in about 3,000 three dram vials. Another 30,000 to 40,000 specimens are in various stages of processing.

Major emphasis is placed upon the quality of the identifications of the material in the collection. To assure a very high level of authoritativeness in the determinations, almost all material is submitted to outside systematists who are recognized experts in their fields for verification. To this end, a cooperating network of about 125 systematists in both domestic and foreign academic institutions has been assembled. Examples of the foreign input into this endeavor follow: Belgium (3 cooperators), Brasil (4), Canada (4), Czechoslovakia (2), England (4), Finland (1), German Federal Republic (2), France (2), Italy (1), Netherlands (1), Spain (1), Switzerland (1), and USSR (1).

The purposes of the International Collection are fourfold, as follows:

1. To survey the soybean-associated arthropods of all soybean-producing areas of the world with major emphasis on the phytophagous species and their parasites and predators,

2. To monitor the major pest species for possible changes in distribution,

3. To aid in predicting insect problems in areas initiating soybean production, and

4. To provide identification services for soybean researchers and producers.

It will be recognized that there are multiple purposes of the collection because it both generates new information, stores accumulated knowledge and provides information and identification services.

In the past year important and extensive acquisitions have been received from El Salvador, Costa Rica, Panama, Colombia and Ecuador in the New World and from Nigeria, Sri Lanka, Korea and the Philippines in the Old World. All collections are accompanied by full sampling data, and they have been generated mainly through the efforts of Dr. Michael Irwin and Dr. Marcos Kogan.

During the year, identifications of soybean-associated material have been provided to workers in Argentina, Brasil, Colombia, Costa Rica, Ecuador, El Salvador, Panama, Peru, Puerto Rico, and Sri Lanka, as well as to workers in the United States.

Comprehensive studies of the soybean-associated fauna of three geographic units are continuing. The fauna of Mexico is being studied in collaboration with Dr. Francisco Pacheco, CIANO/INIA, based on some 20,000 specimens from that country; that of Colombia is being studied in collaboration with Dr. Gilbert Waldbauer, University of Illinois, based on some 10,000 specimens collected by Dr. Waldbauer in Colombia; and the fauna of Brasil is being studied based upon some 40,000 specimens from that country now housed in IRCSA. This latter study is being pursued in collaboration with Dr. Marcos Kogan and Brasilian colleagues.

In addition to these faunal analyses, comprehensive studies of two pest complexes are underway. The bean leaf beetles of the New World are being studied in collaboration with Dr. Kogan, and the stink bugs are being studied with Dr. Irwin. Both of these groups include many major soybean pest species.

Our survey of the New World soybean-associated fauna is nearing completion with material from Mexico, Belize, El Salvador, Costa Rica, Nicaragua, Panama, Colombia, Venezuela, Ecuador, Peru, Bolivia, Brasil, Argentina, Trinidad and Puerto Rico represented in addition to extensive material from the United States. We do not hold material from the Guiana, Paraguay or Uruguay, but we do not expect surprises from those areas; however, we would be very interested in seeing material from Chile.

We would now like to expand our holdings from the Old World, which are now rather spotty. The collection now holds material from Ethiopia, Sudan, Uganda, Nigeria and South Africa from the African continent; from Iran, Pakistan, India, Sri Lanka, Thailand, Indonesia, Malaysia, Philippines, Japan, China and Korea from Asia; and material from Australia.

To identify possible new sources of material for the collection we circulated the attached questionnaire in the fall of 1977. Some 60 responses have been received to date, including 20 from Africa, 5 from Europe and the Near East, 11 from Asia, and 5 from Australia and Oceania.

Name: _____, Region: _____, Country: _____

INTSOY INSECT PEST MANAGEMENT SURVEY QUESTIONNAIRE

Please Complete this Questionnaire and Return as Soon as Possible to:

Dr. William H. Judy/INTSOY
N-515 Turner Hall
University of Illinois
Urbana, Illinois 61801
United States of America

1. Are soybean produced commercially in your country? _____ yes/no

2. Estimated number of hectares under soybean cultivation in your country. _____.

3. Is the commercial soybean production in your country under supplemental irrigation? _____ yes/no

4. How long have soybeans been grown commercially in your country?

   _____.
   1-5 yrs., 5-20 yrs., 20-100 yrs., 100 plus years

5. Number of soybean crops per year in your country _____, in your region _____.
   a. Average dates of planting. 1. _____, 2. _____, 3. _____.
   b. Average dates of pod set. 1. _____, 2. _____, 3. _____.
   c. Average dates of harvest. 1. _____, 2. _____, 3. _____.

6. List in order of importance the major insect pests of soybean in your region.
   1. _____, 2. _____, 3. _____.

7. Are you interested in cooperating with INTSOY in an insect pest management program on soybeans? _____ yes/no

8. Name and address of Entomologist working on soybean insect problems in your region or country.

ENTOMOLOGIST:

NAME: _____
TITLE: _____
ADDRESS: _____
_____
_____
_____

APPENDIX VIII

International Soybean Fungal and Bacterial Disease Research

James B. Sinclair
Professor, International Plant Pathology

I. Introduction

The research in this portion of the program involved interdisciplinary, interdepartmental and international activities and included the transfer of technology from soybean research to that of common bean. Technical research publications during this reporting period include shared authorship with scientists from Colombia (G. E. Galvez), Ethiopia (A. Mengistu), India (Y. L. Nene) and Puerto Rico (M. A. Ellis). Three of the publications are in Spanish. I was co-editor on four books: two on charcoal rot published at the Universidade Federal de Vicosa, Brasil; one on soybean rust published by INTSOY and a fourth on chickpea diseases published by ICRISAT, India. I was an author of three articles, as well as a collaborator, in the book "Diseases, Pests and Weeds in Tropical Crops" published in East Germany. Papers were published in journals from Colombia (Fitopatologicas), Costa Rica (Turrialba), Ecuador (proceedings), England (PANS and Seed Science and Technology), the USA (Plant Disease Reporter, Proceedings of the American Phytopathological Society, and Fungicide and Nematicide Tests) and Illinois (extension publications).

The major thrust of the research was to better understand the effect of various microorganisms on soybean seeds and seed quality and development of control methods. Other research has included similar studies on common bean. The studies on factors influencing soybean seed quality and their control in Illinois has been supported in part by the Illinois Crop Improvement Association and the Illinois Agricultural Experiment Station.

II. Assessment of Factors that Influence Disease

A. Bacillus subtilis (see references 6, 16, 28):

Three papers were published on the association and effect of Bacillus subtilis on soybean seed germination in vitro and emergence in soil. In the paper of Tenne, Foor and Sinclair (28), surface-disinfected soybean seeds were placed on moist cellulose pads in a temperature series of 5°C increments from 15° through 55°C. As temperature increased, the incidence of B. subtilis increased and germination decreased. Seeds stored at 25°, 35°, 40° and 45°C were placed on cellulose pads at 35°C and potato-dextrose agar (PDA) at 25°C at two week intervals for eight weeks. It was found that there was a decrease in germination and concomitant increase in occurrence of B. subtilis as storage temperatures increased, whether assayed at 25° or 35°C. B. subtilis was found in the parenchyma (endoderm) and hour-glass (mesoderm) cell layers of seed coats from surface-disinfected seeds of four cultivars. A method was developed for examination of bacteria in soybean seed coat tissues utilizing formaldehyde vapor and a mixture of absolute ethanol and glacial acetic acid (2:1) as killing and fixing agents.

Schiller, Ellis, Tenne and Sinclair (16) bioassayed 26 surface-disinfested soybean seed lots of the cultivars Bragg, Dare, Hill, Lee 68 and Amsoy 71 from five states for Bacillus subtilis. Dare and Hill seeds contained more B. subtilis than Bragg and Lee 68 seeds. The occurrence of B. subtilis among all seed lots did not differ among states. The occurrence of B. subtilis was inversely proportional to germination in culture plates and field emergence. It was found that Amsoy 71 seeds treated with 500 mg/ml potassium penicillin G in dichloromethane (methylene chloride) (DCM) were protected from decay by B. subtilis allowing higher germination and greater hypocotyl and radicle growth than nontreated seeds on cellulose pads at 40°C.

In the third paper Ellis, Tenne and Sinclair (6) treated Amsoy 71 soybean seeds with streptomycin sulphate at 5, 10, 15, 25 or 35 mg/20 g of seeds. After 4, 12, 24 or 48 hours at 25°C, washed cotyledons were bioassayed. Zones of inhibition of Bacillus subtilis occurred around cotyledons of all treated seeds except controls (nontreated) and those treated with the following rates and times: 5 mg at 4, 12 and 24 hours; 10 mg at 4 and 12 hours; and 15 and 25 mg at four hours. Inhibition zones increased in size with increase in rate and time. Thin-layer chromatography confirmed streptomycin activity in tissues of treated seeds. B. subtilis was consistently isolated from dead and decayed seeds. The occurrence of B. subtilis-decayed seeds was inversely correlated with in vitro germination and emergence in soil, and increased with increase in temperature (25°, 30° and 35°C). Streptomycin treated seeds produced significantly lower occurrence of decayed seeds and significantly higher germination in vitro than nontreated seeds. Seeds of Amsoy 71 and Wells were nontreated or treated with 500 ug/ml K penicillin-G in DCM or DCM alone and stored at 40°C for 8 weeks. Nontreated seeds also were stored at 4°C. Tetrazolium tests showed that the cotyledons of seeds deteriorated at 40°C but not at 4°C. Nontreated seeds that did not germinate at 40°C were decayed by B. subtilis. Seeds treated with penicillin-G in DCM, with DCM alone or nontreated germinated 90%, 22% and 10% respectively, after 8 weeks at 40°C suggesting that DCM may have an effect on either the host tissue or B. subtilis.

B. Age of pod and pubescence (see reference 12):

In an on-going study concerned with the epidemiology of Phomopsis sojae, causal fungus of the soybean pod and stem blight disease, Hepperly and Sinclair (12) published an abstract concerned with pod and seed infection of detached pods inoculated with the Phomopsis sp. They harvested soybean pods containing mature seeds at three stages of senescence. Stage of senescence was determined by pod color: green, yellow, or brown. Pods were noninoculated (control) or inoculated with Phomopsis spp. Pods were either wounded or nonwounded and then placed in a moist chamber at 95% RH at room temperature (22 ± 2C). Visible lesions developed after 2 to 4 days. The majority of lesions developed at the base of trichomes with penetration occurring between epidermal cells. Pods of Chippewa 64 have visibly fewer trichomes and had less

seed infection than Corsoy, Hark, and Harosoy, which have greater number of trichomes. Pods of all cultivars at all three stages were invaded by Phomopsis spp. Seed infection was delayed in green pods with reduced severity and frequency compared to that of yellow and brown pods.

III. Diseased Seeds and Seed Quality (see reference 13)

The compositional changes and the reduction of oil quality was measured in soybean seeds infected with Phomopsis sojae and reported in an abstract by Hepperly and Sinclair (13). Three seedlots of Wells soybean with greater than 20% seedborne Phomopsis spp. were bulked and seed was separated on the presence or absence of visual symptoms of Phomopsis spp. infection. Phomopsis spp. were recovered from 85% of seed with symptoms and 20% from seed without symptoms when seeds were surface-disinfected (.525% NaOCl-10% Chlorox for 4 minutes), plated on sterile potato-dextrose agar, and incubated for 5 days at 25°C. Seeds exhibiting symptoms had 12% germination compared to 86% for symptomless seed. One hundred seed weight, volume, and density was significantly lower in seedlots with visible symptoms. Using a Dickey-John Infrared Analyzer, soybean meal was measured for percentage of oil and protein. Oil and protein content was significantly higher for meal from seed with symptom expression. Meal from seed exhibiting symptoms was gray with a rancid odor. Thiobarbituric acid test, acid value determination and peroxide value determination of oil of seed exhibiting symptoms showed that oil quality was reduced.

IV. Control of Soybean Diseases

A. Seed Treatment (see references 8, 10, 11, 14):

S. R. Foor and Sinclair (8) found that seed treatments could affect seed quality by influencing the fungi associated with the seed at the end of the growing season. Twelve Wells soybean seed lots from plants sprayed with five fungicides were either treated with 500 ug/ml K Penicillin G in dichloromethane plus 0.5 g/100 g seeds Arasan 50 Red or nontreated. The seeds were planted at Isabela Station, Puerto Rico and harvested at maturity and 4 weeks later. Surface-disinfected seeds were bioassayed in potato-dextrose agar culture plates. Germination and occurrence of internally-borne fungi were recorded. There were no differences in germination or occurrence of fungi due to spray. There were differences in microflora with respect to seed treatment and harvest time. Significantly higher levels of Phomopsis spp. and lower levels of Fusarium spp. were recovered from seeds of plants grown from nontreated seeds. Lower levels of Phomopsis spp. and higher levels of Fusarium spp. were recovered from seeds of plants grown from treated seeds. There was more purple-stained seeds from plants grown from treated seeds than nontreated seeds. Thus, seed treatment affects seed quality by influencing fungi associated with the seed at the end of the growing season. Competition between the fungal microflora is altered with seed treatment and affects the type of fungi isolated.

P. R. Hepperly and Sinclair (11), using aqueous polyethylene solutions for treating soybean seeds with antibiotics, reported that Amsoy 71 soybean seeds, soaked 30 minutes or longer in water then dried and planted had seedling emergence below nontreated seed. Germination of seeds soaked four days in aqueous solutions of polyethylene glycol 6000 (PEG) of various concentrations was not different from that of nontreated seed. Seeds soaked in a PEG solution containing 500 ug/ml potassium penicillin G or streptomycin sulphate along or with either thiram or fentin hydroxide resulted in zones of inhibition of Bacillus subtilis on the medium seeded with this microorganism. No such zones formed around seeds soaked in PEG solution alone. Antibiotic activity was detected in seed coats, hypocotyls, epidotyls and cotyledons. Seeds treated in a PEG solution containing penicillin G and thiram retained 85% of their original activity after 15 weeks storage at 25°C. Larger zones occurred around seeds soaked for four hours in PEG solution containing penicillin G than those soaked for one or two hours, but zone size did not increase with longer soaking. Field emergence from seeds treated with penicillin G plus thiram dust was significantly higher than that of nontreated seeds and seeds treated with thiram alone. Antibiotic activity was detected 24 days after planting in seedling cotyledons of seedings grown from seeds soaked in PEG solution containing penicillin G and then dusted with thiram. Seedlings from seeds treated with streptomycin sulphate whether alone or in combination with fentin hydroxide exhibited phytotoxicity symptoms, whereas penicillin G produced phytotoxicity symptoms only when in combination with fentin hydroxide.

P. R. Hepperly and Sinclair (10, 14) reported on two studies on the effects of various seed treatments on emergence and yield under field conditions. In 1976, Wells soybean seeds, harvested in 1975 from plants grown on the University of Illinois Agronomy South Farm, Urbana, were assayed for germination in culture and presence of seed-borne fungal pathogens. Two-hundred seeds were placed on moist cellulose (Kimpac) pads and another 200-seed sample was surface disinfected and placed on sterile potato-dextrose agar (PDA). Both samples were incubated for 6 days at 25 C. On cellulose pads, seeds germinated 68% with 26% Phomopsis sp. and 2% Cercospora sp. On PDA, seeds germinated 64% with 32% Phomopsis sp. and 3% Cercospora sp. Lots of 100 seeds each were either nontreated (control) or treated with one of the treatments shown below. One week later (May 20), the lots were hand planted on the Agronomy South Farm. Treatments were arranged in a randomized complete block design with four replications of 100 seeds each. One-hundred seeds were planted per 6.1 m-row. Emergence counts were taken on June 10 (21 days) and phytotoxicity noted. Seedlings had fully expanded primary leaves and the first trifoliolate was visible. Treatments were hand harvested at maturity (October 1) and total yield and 1,000-seed weights were recorded.

The mean emergence from nontreated seeds was 33%, which was less than half of the laboratory emergence and lower than 28 of the other treatments. Lower emergence resulted in lower yields, but there were no significant differences between treatments in 1,000-seed weights. Significantly ($p = .05$) higher emergence was recorded from seeds treated with polyethylene glycol (PEG)-incorporated penicillin G + Arasan 50 Red then with Arasan 50 Red alone.

Emergence and yield from seeds treated with PEG + penicillin G were not significantly greater than those from nontreated seeds, which suggests that control of bacteria on soybean seeds without fungal control may have little effect on germination. Control of both bacteria and fungi results in rates of emergence comparable to germination readings obtained under laboratory conditions. Phytotoxicity was noted on 28 and 70% of the seedlings from seeds treated with 2 and 4 oz/bu Mertect LSP, respectively, as whitening and necrosis on the edges of the cotyledons. Yellowing and deformation of cotyledons were recorded on a small number of plants from seeds treated with BASF 317 at 60 g/bu. Phytotoxicity was found on seedlings of seeds treated with SSP (MO) Exp. (HB) in the form of planting dwarfing and wrinkling of primary leaves. Seedlings from seeds treated with UBI 1109 at 4 oz/bu had wrinkled, irregular primary leaves with a whitish cast.

In 1977, seed samples were randomly selected from Wells soybean lots harvested from either Benlate-sprayed (considered as "good quality" seeds) or nonsprayed ("poor quality") plants in 1976. The mean (four replications of 100 seed each) percent shriveled seeds and 100-seed weight for seed samples from sprayed and nonsprayed plots were 0 and 18.5g, 2 and 16.5g, respectively; with the germination and internally seed-borne fungi after surface disinfestation (0.5% sodium hypochlorite for 4 minutes) and plated on potato-dextrose agar for 6 days at 25°C being 99% and 13% Alternaria sp. and 80% and 12% Phomopsis spp., respectively. One week prior to planting (May 21) 100-seed lots of the "poor quality" seed were treated with one of the materials listed below. Nontreated "good" and "poor" quality seed lots served as controls. Treatments were arranged in a randomized complete block with four replications and planted with 100 seed per each 6.1-m (20-ft.) row at the University of Illinois Plant Pathology Farm. Stand counts were recorded at 20 days after planting and yields at maturity (135 days after planting).

The mean percent emergence was significantly higher from the nontreated "good" quality seeds than from any other treatment. The highest yield also was obtained from the nontreated, "good" quality seeds. DPX-115B at 2, 4 and 6 oz/cwt., Guardsan 389 at 4 oz/cwt., ME-144-SU LSP at 2 fl. oz/cwt., and Penicillin-G 10^3 units/ml in dichloromethane plus Arasan 50 Red at 2 oz/cwt., produced a significantly higher stand than did nontreated "poor" quality seeds. Seeds treated with DPX-115B at 2 oz/cwt. and Benlate-T at 4 oz/cwt., produced a significantly higher yield than nontreated "poor" quality seeds, and were not significantly different from nontreated good quality seed. Phytotoxicity was noted on plants from seeds treated with Mertect LDP 30% TBZ at 2 fl. oz/bu as a marginal chlorosis on the cotyledons and from seeds treated with acetone, Penicillin-G 10^3 units/ml in acetone, ME-135 at 100 ug/ml in acetone plus Mertect LSP 30% TBZ at 1 fl. oz/bu PEG alone which had a significantly lower emergence than the nontreated "poor" quality seed control.

B. Fungicide Sprays (see reference 7):

In a test conducted in 1975, Foor and Sinclair (7) planted Wells soybeans in the field on May 13 and sprayed with one, two or three applications of nine fungicides before flowering (BF) (June 13), early-flowering (EF) (June 30), early-pod (EP) (July 11), mid-pod (MP) (July 25), late-pod (LP) (August 18) or very-late-pod (VLP) (August 24). Non-sprayed rows served as controls. The plots had four 3.048-meter rows on 76.2-cm centers. The two center rows were rated as to the percentage mature plants (MAT) on August 28. Half of each center row was harvested on September 18 [first harvest (FH)]; the other half was harvested on October 1 [late harvest (LH)]. Plants were threshed with a small-plot thresher and total yield and 1,000-seed weight recorded. All seeds were stored separately at 4°C until bioassayed. Four hundred seeds from the first harvest and 200 seeds from the late harvest were surface sterilized by soaking in a 0.25% sodium hypochlorite solution for 4 min., in 70% ethanol for 2 min., and then rinsed in sterile distilled water. Two hundred seeds per harvest per treatment were plated on Gibco potato-dextrose agar (PDA) in 9-cm culture plates with four seeds in each of 50 plates. After 7 days at 25°C, percentage of Phomopsis spp. (Phom.), total fungi (TF), Alternaria spp. (Alt.) and germination in vitro were recorded. Seeds were considered germinated when the radical was 1.5 times the length of the cotyledons. Two hundred surface sterilized (SS) and 200 nonsurface-sterilized (NSS) seeds from the first harvest were germinated on sterile cellulose pads (Kimpac) (Cell.) at 25°C for 7 days. Each treatment was scored (SC) as to the number of times it was significant from the control for the 15 parameters measured. This rating system was based on the Duncan's New Multiple Range Test.

Germination was higher and the occurrence of Phomopsis spp. and total fungi were lower when fungicides were applied at mid-pod or early-pod plus mid-pod. Bravo and Merteck did not improve seed quality. The best seed quality was obtained from plants sprayed with Benlate, Topsin-M, Duter and RH-3928. Differences between fungicide treatments were more apparent among seeds from the late harvest than the first harvest with respect to yield, 1,000-seed weights, germination in vitro, total fungi, Alternaria spp., and recovery of Phomopsis spp. Seeds from plants sprayed with Benlate, Topsin-M and RH-3928 had significantly more Alternaria spp. than seeds from control plants.

V. Outreach and Technology Transfer (see references 1, 2, 3, 4, 5, 9, 15, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27)

The 1977-78 grant year represented, in part, a period of summary of research for outreach and technology transfer activities. Our efforts involved the publication of several summary books and articles, as well as research papers in Spanish and English.

One of the major international outreach activities is represented by the publications of two books on Macrophomina phaseolina, causal agent of charcoal rot. These were coauthored by O. D. Dhingra and J. B. Sinclair

and printed by the Universidade Federal de Vicosa University Press, Vicosa, Brasil. Charcoal rot is a major disease of many crops, including soybeans, in the warmer areas of the tropics and subtropics. Another international outreach activity, which also represents some technology transfer, was the collaborative assemblage into book form of "An Annotated Bibliography of Chickpea Diseases", coauthored by an Indian (Y. L. Nene), an Ethiopian (A. Mengistu) and two Americans (D. J. Royse and J. B. Sinclair) and published by ICRISAT, Hyderabad, India.

As part of the outreach activities, the author participated in three conferences, held in the 1976-77 reporting period, and gave invitational papers which appeared in the proceedings of these meetings in this reporting period. The proceedings of two major workshop/seminars on soybean rust, one held in Mayaguez, Puerto Rico and the other in Manila, The Philippines; and the proceedings of the INTSOY - sponsored conference at Chiang Mai were published during this reporting period.

Several summary articles representing additional outreach activities were published in Illinois in proceedings of two workshops, one with M. C. Shurtleff and B. J. Jacobsen, extension plant pathologists; in Ecuador (in Spanish) in the proceedings of a workshop; in England (PANS) as a review of soybean diseases of world importance; in West Germany as part of a book on "Diseases, Pests and Weeds in Tropical Crops"; and in the proceedings of the INTSOY Conference for Asia and Oceania, Chiang Mai, Thailand.

There were several research or technical papers published concerned with the transfer of technology from the work done on soybeans to common bean (Phaseolus), cooperating with M. A. Ellis, Plant Pathologist, UPR, Mayaguez and G. E. Galvez, Plant Pathologist, CIAT, Cali, Colombia. It was found that many of the microorganisms causing seed deterioration and loss of quality in soybean seeds were the same in common bean (Phaseolus) seeds. When similar methods of fungicide treatments were applied to either the seeds or the foliage of common bean the microorganisms were controlled and seed quality was improved. Results from these studies were published in Spanish (Fitopatologicas, Colombia, and Turrialba, Costa Rica) and in English (Fungicide and Nematicide Tests).

1. Dhingra, O. D., and J. B. Sinclair. 1977. An annotated bibliography Macrophomina phaseolina 1905-1975. Univ. Federal de Vicosa, Vicosa, Brasil and Univ. of Illinois, Urbana. 244p.

2. Dhingra, O. D., and J. B. Sinclair. 1978. Biology and pathology of Macrophomina phaseolina. Universidade Federal de Vicosa, Brasil. 166p.

3. Ellis, M. A., G. E. Galvez and J. B. Sinclair. 1976. Hongos internamente portados por la semilla y caldad de la semilla de frijol (Phaseolus vulagris L.) cosechado en fincas de pequenos agricultores en cuarto pequenos agricultores en cuarto pequenos agricyltores en cuatro departamentos de Colombia. Noticias Fitopatologicas 5(2):79-82.

4. Ellis, M. A., G. E. Galvez and J. B. Sinclair. 1977. Control of dry bean seed infection by Colletotrichum lindemuthianum with foliar fungicides. Fungicide and Nematicide Tests 32:70.

5. Ellis, M. A., G. E. Galvez and J. B. Sinclair. 1977. Efecto del tratamiento de semillas de frijol (Phaseolus vulgaris) de buena y mala c alidad sobre la germinacion en condiciones de campo. Turrialba 27:37-39.

6. Ellis, M. A., F. D. Tenne and J. B. Sinclair. 1977. Effect of antibiotics and high temperature storage on decay of soybean seeds by Bacillus subtilis. Seed Sci. & Technol. 5:121-129.

7. Foor, S. R., and J. B. Sinclair. 1977. Effects of fungicide sprays on soybean maturity, yield and seed quality. Fungicide and Nematicide Tests 32:122-123.

8. Foor, S. R., and J. B. Sinclair. 1977. Preplant seed treatment alters microflora of harvested soybean seeds. Proc. Amer. Phytopathol. Soc. 4:155 (Abstr.)

9. Ford, R. E., and J. B. Sinclair, eds. 1977. Rust of soybean; the problem and research needs. Intern. Agr. Publ. INTSOY No. 12, Univ. of Illinois, Urbana. 110p.

10. Hepperly, P. R., and J. B. Sinclair. 1977. Solvents, antibiotics and fungicides for treatment of soybean seeds. Fungicide and Nematicide Tests 32:190-191.

11. Hepperly, P. R., and J. B. Sinclair. 1977. Aqueous polyethylene glycol solutions for treating soybean seeds with antibiotics. Seed Sci. & Technol. 5:95-101.

12. Hepperly, P. R., and J. B. Sinclair. 1977. Pod and seed infection of detached soybean pods inoculated with Phomopsis spp. Proc. Amer. Phytopathol. Soc. 4:167 (Abstr.)

13. Hepperly, P. R., and J. B. Sinclair. 1977. Reduced oil quality and compositional changes in soybean seed infected with Phomopsis spp. Proc. Amer. Phytopathol. Soc. 4:167 (Abstr.).

14. Hepperly, P. R., and J. B. Sinclair. 1978. Soybean seed treatments. 1977 Fungicide and Nematicide Tests 33: (in press).

15. Nene, Y. L., A. Mengistu, J. B. Sinclair and D. J. Royse. 1977. An annotated bibliography of chickpea diseases, 1921-1976. Intern. Crops Res. Instit. for the Semi-Arid Tropics (ICRISAT), Hyderabad, India.

16. Schiller, C. T., M. A. Ellis, F. D. Tenne and J. B. Sinclair. 1977. Effect of Bacillus subtilis on soybean seed decay, germination, and stand inhibition. Plant Dis. Reptr. 61: 213-217.

17. Shurtleff, M. C., B. J. Jacobsen and J. B. Sinclair. 1978. Fungicides, disinfectants, grain preservatives, surfactants, and soil-disinfesting chemicals. In: 30th Custom Spray Operators Tng. Sch. Proc. p. 345-367. Univ. of Illinois, Urbana.

18. Sinclair, J. B. 1977. Seed-borne microorganisms and their control. p.40-43. In: R. M. Goodman, ed. Expanding the use of soybeans, Proceedings of a Conf. for Asia and Oceania. INTSOY Publ. No. 10., Univ. of Illinois, Urbana.

19. Sinclair, J. B. 1977. Enfermedades importantes de soya. p.58-65. In: Memorias Seminario Internacional de la Soya. Ministerio de Agricultura y Ganaderia, Guayaquil, Ecuador.

20. Sinclair, J. B. 1977. Infectious soyabean diseases of world importance. PANS 23:49-57.

21. Sinclair, J. B. 1977. Soybean rust in the Western Hemisphere. p.18-21. In: R. E. Ford and J. B. Sinclair, eds. Rust of soybean: the problem and research needs. INTSOY Publ. Series No. 12, Univ. of Illinois, Urbana.

22. Sinclair, J. B. 1977. Control of soybean rust by means other than breeding for resistance. p. 85-88. In: R. E. Ford and J. B. Sinclair, eds. Rust of soybean: the problem and research needs. INTSOY Publ. Series No. 12, Univ. of Illinois, Urbana.

23. Sinclair, J. B. Workshop on rust of soybeans in the Western Hemisphere. Soybean Rust Newsletter 1:19.

24. Sinclair, J. B. 1977. Pseudomonas glycinea Coerper. p.54-55. In: J. Kranz, H. Schmutterer and W. Koch, eds. Diseases, Pests and Weeds in Tropical Crops. Verlag Paul Parey, Berlin.

25. Sinclair, J. B. 1977. Phytophthora megapserma Drechs. var. sojae. A. A. Hildeb. p.80-82. In: J. Kranz, H. Schmutterer and W. Koch eds. Diseases, Pests and Weeds in Tropical Crops. Verlag Paul Parey, Berlin.

26. Sinclair, J. B. 1977. Macrophomina phaseolina (Tassi) Goid. p. 217-218. In: J. Kranz, H. Schmutterer and W. Koch, eds. Diseases, Pests and Weeds in Tropical Crops. Verlag Paul Parey, Berlin.

27. Sinclair, J. B. 1978. Soybean seed quality, seed pathology and seed testing. 1978 Illinois Crop Protection Workshop. Mar. 9 p.

28. Tenne, F. D., S. R. Foor and J. B. Sinclair. 1977. Association of Bacillus subtilis with soybean seeds. Seed Sci. & Technol. 5:131-137.

APPENDIX IX

Soybean Seed Storage Under Tropical Conditions

Errol D. Rodda
Professor of Agricultural Engineering

Four hundred thirty-two, 200-g samples were prepared using Woodworth seed grown in Puerto Rico at Isabela. The storage conditions were designed to correspond to the resources available to farmers for seed storage in the tropics. The variables were: two storage conditions where S_1 = shelf-stored in ambient conditions, and S_2 = stored in cardboard boxes with about 15 cm of rice hull insulation; three initial moisture levels were M_1 = 13%, M_2 = 10% and M_3 = 7% moisture content, dry basis; four containers where C_1 = sealed metal can, C_2 = metal can with 1.0 mil plastic lining, C_3 = fertilizer jute bag with 1.0 mil plastic lining, and C_4 = cotton cloth bag; three storage periods where T_1 = 3 months, T_2 = 6 months, and T_3 = 9 months; and two seed treatments where L_1 = treated with thiram (2.08 g/kg) and L_2 = untreated seeds.

Seeds were spread in about a 2.5-cm layer on the floor of a cold storage room (4 C) for several weeks until their moisture content reached about 14%. The seeds were then dried using slightly heated air in a laboratory dryer of about 32 to 35 C until three desired moisture levels were attained. Approximately one-third of the seeds were removed at the appropriate moisture level. The seeds of the appropriate moisture level were sealed in a double layer plastic bag until the drying process was complete. The seeds were then divided into 200-g samples and placed into each of the appropriate containers.

Samples were removed at the end of each storage period and percentage moisture (taken by a Dicky-John moisture tester) was recorded. Two hundred seeds from each replication were planted in the sandbed at Isabela. The samples stored in sealed tin cans maintained their original percentage of moisture through 6 months and had dropped only 1% at the 9-month sampling date (Table 1).

The unsealed tin container held moisture relatively constant as did the fertilizer bag.

Soybeans in cloth bags, however, initially gained moisture after 3 months. Within 6 months all samples gained moisture to about 13%. All samples lost moisture to about 10.5% by the end of 9 months.

There were no significant changes in moisture content with respect to seed treatment in insulation (Table 1).

All five factors studied were statistically significant in the maintenance of emergence in sand. The most significant single factor was initial moisture content. Since the sealed tin containers serve to hold moisture

constant, emergence was relatively unchanged for the first 6 months of storage at 7%. However, it began to drop off after 9 months of storage. Seed at 10% began losing viability after 3 months and gradually fell to about 55% after 9 months. Germination of seed lots that started at 13% moisture fell rapidly in 3 months and did not emerge after 6 months (Table 2).

The emergence pattern for the nonsealed tin container and the fertilizer bag followed the same general pattern as the sealed tin can except the 9-month emergence at 10% initial moisture was somewhat lower. For seed stored in cloth bags, all treatments lost significant emergence in the first 3 months and after 6 months seed did not emerge (Table 2).

The rapid loss of germination in storage in the tropics under the conditions of this experiment was directly related to the percentage of moisture level of the seed in storage and the time the seeds were in storage. The best containers for storage are those that maintain a low initial moisture content.

The seeds treated with thiram did not germinate any better than the untreated seeds. Insulation also had no effect of practical significance.

Parallel sealed can storage tests in Urbana at 25° C (the mean ambient temperature of Puerto Rico) gave germination results similar to those obtained in Puerto Rico. The seed multiplied in Puerto Rico did not store as well as the parent seed from Illinois.

Table 1. Mean percentage moisture of Woodworth soybean seed stored in various containers; at three initial moisture levels; either noninsulated (N) or insulated (I) in rice hulls; for 3, 6 and 9 months either nontreated (NTR) or treated (TR) with 2.08 g/kg seed thiram, Mayagüez, 1976.

			Storage time (months) and seed treatment					
			3		6		9	
Container	Initial moisture (%)	Insu-lation	NTR	TR	NTR	TR	NTR	TR
Sealed tin can	7	N	7.4	6.8	7.9	8.0	6.4	6.3
	7	I	7.3	7.5	7.6	7.4	6.3	6.4
	10	N	9.9	9.5	10.5	9.8	9.8	9.6
	10	I	10.0	9.6	10.0	9.9	9.6	9.4
	13	N	13.3	13.0	13.4	13.3	12.1	12.0
	13	I	13.5	13.0	13.5	13.0	12.3	--
Nonsealed tin can	7	N	8.0	7.9	8.7	9.0	8.6	8.5
	7	I	7.8	8.0	9.0	11.0	8.9	9.3
	10	N	10.3	9.1	10.8	10.4	10.3	10.1
	10	I	9.8	8.5	11.1	10.7	10.7	9.8
	13	N	13.4	13.0	13.2	13.1	12.2	11.7
	13	I	12.1	10.6	13.6	13.4	12.3	11.7
Fertilizer bag (plastic lined)	7	N	8.4	8.6	9.2	9.8	7.9	10.0
	7	I	8.3	8.9	9.8	10.0	9.5	10.4
	10	N	10.1	10.1	11.2	10.8	10.1	11.6
	10	I	10.4	10.3	11.0	11.1	10.7	10.6
	13	N	13.3	12.4	13.5	13.4	12.0	12.1
	13	I	13.3	13.2	13.5	13.2	12.0	11.6
Cloth bag	7	N	12.8	13.6	13.5	11.8	10.9	10.6
	7	I	12.1	12.8	13.2	13.2	10.6	10.7
	10	N	12.6	13.0	13.1	12.5	10.0	10.8
	10	I	12.8	12.9	13.2	12.8	10.4	10.4
	13	N	13.3	13.1	13.0	13.1	11.0	10.9
	13	I	12.9	13.0	12.9	13.2	10.6	10.6

Table 2. Mean percentage emergence in sand of Woodworth soybean seed stored in various containers; at three initial moisture levels; either noninsulated (N) or insulated (I) in rice hulls; for 3, 6 and 9 months; either nontreated (NTR) or treated (TR) with 2.08 g/kg seed thiram, Mayagüez, 1976.

Container	Initial moisture (%)	Insulation	Storage time (months) and seed treatment					
			3		6		9	
			NTR	TR	NTR	TR	NTR	TR
Sealed tin can	7	N	89	91	83	88	62	76
	7	I	91	89	90	89	92	79
	10	N	88	85	70	76	44	50
	10	I	82	82	76	72	60	29
	13	N	38	51	2	0	0	0
	13	I	42	40	2	0	1	--
Nonsealed tin can	7	N	92	90	86	88	84	83
	7	I	90	92	85	83	90	72
	10	N	82	82	66	63	22	34
	10	I	82	76	54	57	8	20
	13	N	52	33	0	0	0	0
	13	I	34	42	0	0	0	0
Fertilizer bag (plastic lined)	7	N	92	91	89	81	81	76
	7	I	96	91	87	83	86	63
	10	N	80	85	67	54	23	16
	10	I	84	83	57	52	8	13
	13	N	36	40	0	0	0	0
	13	I	36	35	0	0	0	0
Cloth bag	7	N	70	57	0	0	0	0
	7	I	38	15	0	0	0	0
	10	N	50	49	0	0	0	0
	10	I	42	29	0	0	0	0
	13	N	51	41	0	0	0	0
	13	I	26	13	0	0	0	0

Table 3. Mean percentage germination of Illinois and Puerto Rico produced Woodworth soybean seed stored in sealed metal containers; at three initial moisture levels; at two temperatures; for 3, 6, and 9 months.

Lot	Initial Moisture %	Temperature °C	Storage time (months) 3	6	9
	7	3	70	90(0.8)*	83(0.8)
	7	25	78	87(2.3)	86(2.0)
Illinois	10	3	79	86(0.9)	79(0.7)
	10	25	80	87(2.9)	80(4.4)
	13	3	84	87(1.3)	84(0.9)
	13	25	74	33(8.1)	0(11.5)
	7	3	80	85	79
Puerto	7	25	81	83	67
Rico	10	3	82	84	83
	10	25	86	88	54
	13	3	84	87	85
	13	25	84	54	1

*CO_2 concentration (%) in container

Table 4. Mean percentage germination of Woodworth soybean seed stored in sealed metal containers; at three initial moisture levels; at two temperatures; for 3, 6, and 9 months; either treated (TR) or nontreated (NTR) with 2.08 g/kg thiram.

Initial Moisture %	Temperature °C	Storage time (months) and seed treatment 3 NTR	3 TR	6 NTR	6 TR	9 NTR	9 TR
7	3	80	83	79	83	78	76
7	25	77	75	71	73	76	53
10	3	75	80	82	75	77	68
10	25	64	77	62	70	36	46
13	3	82	80	78	77	74	61
13	25	55	65	16	17	1	3