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

Final Report on
Contract AID/TA-C-1294
April 1, 1976 to March 31, 1979

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

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

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REPORT SUMMARY

A. Statistical Summary

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

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3. Contract Period: April 1, 1976 - March 31, 1979

4. Period Covered by Report: April 1, 1976 - March 31, 1979

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

6. Total Expenditures for Report Period: $1,947,594

B. Narrative Summary

Excellent progress was made in all areas of responsibility. A worldwide phased system of variety testing is in place. Promising work on the identification of soybean germplasm resistant to soybean mosaic virus has uncovered two crosses, each with a dominant allele for resistance to SMV. Cooking methods, rather than variety, appears to be more important in the cooking quality of selected varieties of soybeans with the use of bicarbonate solutions increasing the tenderness of soaked and cooked soybeans nearly three fold.

A collection of *Rhizobium japonicum* strains has been assembled and is being maintained at the INTSOY microbiology laboratory in Puerto Rico. Research was conducted on the ability of *R. japonicum* strains to survive at elevated soil temperatures found in the tropics and subtropics and on the rates of *R. japonicum* needed to produce inoculum economically. Alternatives to peat as an inoculum carrier were studied and treated coir dust shows promise. An alternative low energy method for sterilizing plant containers used in Rhizobium quality control and research was developed.

Basic information systems on soybean germplasm, literature and arthropods are serving soybean workers in LDC's. Information on current and projected world soybean production and trade is being generated. The economic potential for LDC's to commercially process soybeans for oil, meal, and food products is being studied. A workshop on soybean rust, a major disease affecting the crop in Asia and a potential threat

the six month phase-out period a procedure for preparation of a low technology soy beverage was completed, filtering devices required for the preparation of the soy beverage were evaluated, and a simple device for separation of cracked soybeans into hull and cotyledon fractions was designed, constructed and evaluated.

Results of research done under, and in cooperation with, this contract have been widely published in professional journals and other scientific publications. A listing of the considerable number of articles produced in connection with this contract is found in the Appendix to this report.

A proposal for a successor research contract has been submitted, reviewed and approved by RAC, and is in process of execution. Because of time constraints the new contract will not be ready for implementation on April 1, 1979 and a brief extension of contract AID/TA-C-1294, at current levels of activity and funding is in process.

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

A seventh objective was completed during the first year of operation, namely "Phasing out of previous activities on home processing of soybeans by October 31. 1976." A final report entitled "Soybean Processing Using Low Level Technology" was submitted to the Agency in December, 1976.

B. Background

In April, 1973, a contract was awarded to the University of Illinois at Urbana-Champaign (UIUC) by the U.S. Agency for International Development calling on the University to "perform a research and development program directed toward the development of improved varieties of soybeans." The contract expired in March 1976, by which time sufficient demonstrable progress had been made in soybean production, protection and processing training, communication and linkage and network development to warrant the award of a succeeding contract. The new contract was designed to extend and expand efforts begun under the previous contract to give greater attention to emerging problems in pest management, storage and handling of soybean seed, economics, Rhizobium technology and dissemination of information.

This report presents a narrative description of the progress made toward achieving the objectives listed in Section A. Data are publishing are available to substantiate findings but are not

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ISVEX was initiated in 1973 as the first part of the genetic improvement program of INTSOY. Since then, two other preliminary variety evaluation trials, SIEVE and SPOT, have been developed and the soybean breeding program in Puerto Rico injects varieties into these trials. The objectives are to evaluate soybean cultivars (varieties) for wide environmental adaptability and to provide countries with improved cultivars with desirable agronomic characterisitcs to be used in the direct introduction to farmers or for use in soybean breeding programs. Data recorded by cooperators in this program provide information about the response of cultivars. This response is analyzed for high stable yield and other desirable agronomic characteristics. Other important dividends have been obtained through accumulation of more knowledge about the response of soybeans to different management practices and about the effects of ranges of temperature and day-length, as well as various soil conditions. As results accumulate from more growing seasons, the objectives of this trial system are being attained. For the first time, multi-year mean for desirable characteristics of cultivars can be calculated within and across environmental zones, for geographical area within zones, and for selected countries. This has improved the capability of INTSOY for expanded interpretation of results and permits more accurate prediction of the behavior of cultivars under different environmental conditions. The importance of careful cultivar evaluation and selection, as well as improved management during production and harvesting, has been clearly demonstrated.

Since its inception in 1973, ISVEX has been conducted at 1,153 locations in 107 countries. Fifty-seven cultivars have been evaluated in environmental zones from below sea level to over 1800m altitude and from 40°N to 40°S latitudes. Mean site yields have ranged from lows of 500-600 kg/ha to highs of more than 6000 kg/ha. It is appropriate to review the degree to which the objectives have been met for this significant part of the INTSOY variety evaluation system. The objectives are listed and commented on below.

Objective 1: To test the adaptation of soybean cultivars under a wide range of environmental conditions. Since 1973, 57 soybean cultivars have been grown at virtually all latitudes and at altitudes up to 1860m from the equator to 40° north and south. Trials have been grown on soils which are acid, alkaline, and saline; sand to clay to silt in texture; and rainfed and irrigated, at a total of 1153 sites. The mean yields have ranged from 1191 to 3996 kg/ha with a range of 550 to more than 6000 kg/ha at individual sites. A body of information has been built up which clearly demonstrates that soybeans as a crop are widely adapted, that some soybean cultivars are more widely adapted than others, and that there is a potential in the germplasm for additional improvement in yield and desirable characteristics.

Objective 2: To provide research workers with an opportunity to compare local and introduced cultivars. During these six years 1153 trials have been conducted in 107 countries by cooperators who are

entries in 1978 and it is expected that there will be 15-20 new entries in 1979. The number of evaluation sites has been increased from six in 1976 to 18 in 1979 in order to obtain a more precise evaluation of the new varieties under different environmental conditions. Six entries from the 1977 and 1978 SPOT trials were selected for inclusion in the 1978 and 1979 ISVEX.

The SIEVE trial was organized in 1978 and has been continued in 1979. The objective is to tap the pool of germplasm being developed in country soybean breeding programs throughout the world. Plant breeders contributed 48 cultivars for the 1978 trial which was planted in Ecuador, Puerto Rico and Florida. In 1979 soybean breeders contributed cultivars to the new trial which will be planted at the same locations. Selections have been made from the 1978 SIEVE trial and entered into the 1979 SPOT trial. When the SIEVE, SPOT, and ISVEX 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 soybean breeding programs in the world could effectively contribute to the tropical and sub-tropical genetic improvement program.

This comprehensive variety testing program depends upon the voluntary collaboration of cooperators. The INTSOY Agronomist acts as the coordinator for the soybean variety evaluation trials. The coordinator supplies the seed for all experiments (except for the local variety which is included at the option of the cooperator), the inoculant, and a standard set of instructions and data collection sheets. The cooperator in each country provides the land, labor, fertilizer, and management necessary for the experiment. 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 include yield, root nodulation, days to flowering and maturity, plant height at maturity, estimates of lodging and shattering, rating for seed quality and measurement of percentage germination of the harvested seed. Samples of each of the varieties are also returned to INTSOY for protein and oil content analysis.

The stage is now set for INTSOY to counsel more accurately with those countries interested in developing a soybean production program to help them select better adapted varieties and to outline more precise production and utilization programs. Because of the knowledge gained through the INTSOY variety trials, the response of varieties can be more accurately predicted in specific environmental conditions. Also, the response of soybeans to specific crop husbandry practices can be better predicted as well as the usefulness of the harvested grain for a high protein food source for people. More knowledge has been gained about proper methods for harvesting and storage of soybeans for seed which is essential to any efficiently functioning crop production system in any country in the world.

accession to accession, (b) there might be accessions which do not transmit the virus through seed, and (c) if such seed nontransmitting material were available, could it be used to develop adapted, agronomically suitable cultivars or advanced lines for testing in LDC soybean programs.

Last year's report listed five tropical lines and 19 temperate lines that appeared to have very low or nil rates of SMV seed transmission. These studies have been carried further with the temperate germplasm accessions to test more lines at the 1000 seed level. For the tropical lines, all candidate lines were tested in 1977-78 at the 1000 seed level. The 5 lines identified as apparent nontransmitters plus 5 lines shown to be transmitters were planted in 1978 in a randomized, split plot design to compare the yield impact of infection on transmitters vs. nontransmitters and to produce enough seeds to test the apparent nontransmitters at the 10,000 seed level.

The yield data confirmed that the lines selected for nontransmission had relatively higher yields (ie. were more tolerant to infection) then those that had not been so selected. This is probably because the only lines that could be tested for nontransmission at the 1000 seed level were those that had produced sufficient seed. The most severely affected accessions were not tested because of a lack of seeds. The seed transmission data at the 10,000 seed level for this experiment will be collected in June 1979.

Availability of resistance to SMV in the tropically-adapted soybean lines INTSOY makes available to its cooperators in national programs throughout the world, coupled with an understanding of the pathogenic variation among virus isolates in various area of the world (see below), is a continuing long-range goal of the INTSOY plant virus/breeding research program. Achievement of the first stage of this goal has now been realized with identification of useful germplasm and classification of SMV strains for virulence on these and other accessions resistant to SMV.

Insect Control Through Genetic Improvement. Selective studies toward development of insect resistant genetic material were conducted with some encouraging preliminary results. Two INTSOY scientists integrated their work into a breeding program started in 1971 that seeks to incorporate resistant traits of two PI's into commercial varieties of soybeans. Although the PI's had originally been tested 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.

Segregating populations arising from crosses involving two sources of resistance to the Mexican bean beetle were screened and selected for

4. The relative tenderness among varieties varied with soaking and cooking treatment. A predicted tender variety was not always more tender than another predicted tender variety under all four soaking and cooking conditions, e. g., listed among the six most tender varieties in all four treatments in the 1976-1977 report were Amsoy '71, Hark and Kanrich and in the 1977-78 report were Cobb, Ransom and Semmes. However, Bonus, Hodgson and Williams varieties were the most consistently tender in both years. Therefore, they were chosen to represent the tender varieties in the 1978-79 study.

5. Certain soybean characteristics correlated with the tenderness of the cooked whole soybeans. These were: change in weight after soaking and cooking, change in weight after soaking only, initial moisture content, density of bean, volume of bean, and rehydrated volume of bean.

Other studies on cooking/nutritional aspects of soybeans with potential ramifications for varietal improvement were conducted. The rate of hydration of soybean variety was investigated for the purpose of decreasing soak time prior to cooking to determine whether cooking methods could be further improved. Samples containing bicarbonate solutions hydrated better than samples without bicarbonate, and the total time required for soaking/cooking operations may be reduced.

A nutritional study on the effect of the ratio of corn to soy on the PER of corn:soy flakes was completed. Milled, fractional whole corn was blended with soy flour in eleven combinations. The proximate composition, amino acid profile and PER of samples were determined. The corn fraction used affects composition and nutritional quality of the corn:soy blend.

Results indicated that the finer corn fractions were lower in protein, fat, fiber and ash. This indicates that the finer fractions contain less hull and germ which are high in protein, fat, fiber and ash. When the corn:soy ratio was changed from 4:1 to 2:1, protein content was increased from about 15% to 19%. The increase in protein content of the blend, with increasing proportions of soy, directly relates to the higher protein content of the soy flour as compared to that of the corn. The fat and fiber contents also varied with the corn:soy ratio and corn fraction used. As the ratio of corn to soy decreased, fat and fiber content increased.

The PER values of the corn:soy products were significantly different with the various size fractions of the milled corn samples. Corn:soy blends containing finer fractions of whole corn (through 35 mesh screen) received the highest PER, whereas commercial corn meal had the lowest PER.

has been supplied in such instances from Agricultural Laboratories, Inc. Columbus, Ohio and the Nitragin Sales Corporation, Milwaukee, Wisconsin.

Screening *Rhizobium japonicum* strains for growth at elevated temperatures. In tropical and subtropical areas high soil temperature may be a significant detrimental factor to the establishment of applied *Rhizobium japonicum* in the seed zone and to the survival of these *Rhizobium* from one year to the next. Without a sufficient quantity of viable rhizobia surviving the time from inoculation into the soil until active soybean root elongation, insufficient nodulation may result which could cause plant nitrogen deficiency and yield loss later in the season. The influence of high soil temperature may also play a significant role in determining the length of time the *R. japonicum* population can survive in the soil. Once a location has successfully grown nodulated soybeans and thus obtained an established population of *R. japonicum*, the rate of decline of this population may be strongly influenced by environmental factors such as high soil temperature.

Four experiments have been conducted with a total of 31 strains of *R. japonicum* on agar plates in the laboratory to screen 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 and fourth experiments.

Each strain of *R. japonicum* was grown in broth medium and this was used to inoculate agar plates prepared from the same medium. Agar pour plates of each strain were placed in incubation chambers at the following temperatures 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°; Experiment FOUR - 30°, 35°, 36°, 37.5°, 39° and 40°C.

For each experiment the strains ability to grow at a specific temperature was evaluated by making the following observations: the number of days required to obtain a visable colony, an estimate of the average diameter after 10 days growth, and the number of colonies after 6 days incubation. Plates which did not have visable growth after 7 days incubation at an elevated temperature were transferred to the 30°C incubator and in all cases no growth developed. This indicates that the bacteria were killed at that temperature, and also that the bacteria do not have a survival mechanism at elevated temperatures which would allow growth once a lower and more favorable temperature was obtained.

When comparing the various incubation temperatures utilized, *R. japonicum* strains grew most rapidly and profusely when incubated at 30°C. Twelve strains were visable one day sooner at 30° than at any other incubation temperature, and 15 strains obtained a larger colony diameter after 10 days at 30°C.

The highest level of inoculation (3,900,000,000 *R.*/cm, which is approximately 1000 times the rate of a commercial granular soil inoculant) provided the highest number of both tap root and total nodules. However, these values were not statistically larger than that obtained with the next 2 lower treatments for tap root nodules or next 3 lower treatments for total nodules. Evaluating the treatments which approximate the rates applied with a commercial seed applied inoculant (treatment containing 39,000 *R.*/cm) and a commercial granular soil inoculant (3,900,000 *R.*/cm) indicate the following conclusion:

> Inadequate tap root nodules (1.4/plant) and total nodules (2.5/plant) were obtained with the rate approximating a seed applied inoculant. The rate approximating granular soil applied inoculant produced 8.7 tap root nodules and 21.1 total nodules/plant. These values were significantly larger than that obtained with the seed applied rate and were not significantly less than values obtained with the treatment providing 390,000,000 *R.*/cm.

In summary, inoculating rates of *R. japonicum* equal to granular soil inoculant produced nodulation and seed yield greater than that obtained with inoculating rates approximating a standard seed applied inoculant.

The matter of effective rates of Rhizobium application also has economic consequences in the costs of producing inoculants with extremely high rates of rhizobia. To a small farmer introducing soybeans on new land it is important to select an inoculant with sufficient rhizobia to obtain satisfactory nodulation and yields without unduly increasing production costs by purchasing expensive inoculants with more rhizobia than are required.

The question of how many rhizobia are required is difficult to answer because different rates may be needed depending on the soil, climate and other conditions. Therefore it should be the goal to produce an inoculant which will provide adequate nodulation under severe conditions. Severe conditions should be defined as conditions not favorable for rhizobia, but still capable of producing a significant yielding soybean plant.

Ar experiment was conducted to evaluate some inoculating rates and carriers which are presently available as commercial inoculants. The experiment was planted at the Isabela substation in Puerto Rico on a site without *R. japonicum*. The treatments included an uninoculated control, 100 lb/A. nitrogen fertilizer, standard rate of seed applied peat inoculant, triple rate of seed applied peat, granular soil inoculant and a liquid soil inoculant. The inoculants were all prepared in the INTSOY microbiology laboratory with one batch of *R. japonicum* culture so that the uniformity between inoculants was maximized and only inoculant carriers and applied rates of *R. japonicum* were the variables.

hydroxide (NaOH) washed (treated) coir. The NaOH washing was performed to remove potential rhizobial inhibitors from the coconut coir.

Inoculants were prepared with the four carriers using two different cross inoculant groups of *Rhizobium: R. japonicum* for soybeans, and a cowpea group *Rhizobium*. After the formulation each carrier was initially sampled for pH, moisture, rhizobial counts, and bacteria, actinomycete and fungal contamination counts. Following the initial sampling all carriers were sealed in a plastic bag and placed in a 35°C incubator to provide a simulated tropical stress temperature. Longevity of the *Rhizobium* populations in the inoculants was periodically determined by plate counts and further verified by plant nodulation tests.

Results indicated that coir had a higher organic matter content and moisture holding capacity than peat or muck. Because of its physical consistency coir could not be milled as finely as the other carriers which lead to decreased seed adherance. Initial pH for peat and coir was adjusted with lime (calcium carbonate) to fall between 6.8 and 7.8. Slight decreases in pH were recorded for all inoculants but limed inoculants had higher pH values and fewer rhizobia than nonlimed inoculants. Moisture levels in the inoculants dropped by 3 to 8 percent but these losses did not seem to affect longevity of rhizobia. Both strains of *Rhizobium* multiplied in peat and treated coir but not in other inoculant carriers. Plate counts showed that numbers of bacterial contaminants reached the same level in all inoculants and the presence of high numbers of bacterial contaminants made it difficult to enumerate populations of *Rhizobium*. Populations of fungi and actinomycetes were highly variable from carrier to carrier and were not related to survival of rhizobia in the inoculants. During the first 6 weeks of the experiment, in cowpea inoculants, treated coir had higher populations of rhizobia than peat or muck inoculants. For soybean inoculants, peat had the highest numbers of rhizobia followed by treated coir, coir and muck. These results indicated the presence of interactions between strains of *Rhizobium* and the inoculant carrier materials. Plant inoculation tests in the greenhouse showed that for both species of *Rhizobium*, viable bacteria were not detectable in peat after 6 weeks incubation at 35°C. Between 6 and 8 weeks *Rhizobium* populations of both species in coir fell below 100,000 viable cells/gm. and remained at this level. After 4 months storage, *Rhizobium* populations in treated coir and muck were between 100,000 and 10,000,000 per gram.

It may be concluded from these studies that carriers such as treated coir dust may equal peat as carrier for *Rhizobium* inoculants under tropical conditions. Also, for greatest accuracy, enumeration of populations of rhizobia from contaminated inoculants should be verified by plant nodulation tests.

seedling emergence increased the number of tap root nodules, total number of nodules and nodule weight per plant decreased. There were more instances of significance and higher negative correlation coefficients between the number of days to emerge and the number of tap root nodules than between the number of days to emerge and total number of nodules or nodule weight per plant. This indicates that tap root nodulation is influenced more by seedling vigor than are total number of nodules or nodule weight per plant.

This study suggests that experiments intended to evaluate the amount of initial soybean nodulation should utilize seedlings of uniform vigor. This may assist in reducing undesirable variables in plant growth which may influence soybean nodulation.

Soybean nodulation as influenced by weed competition. Dr. Guillermo Riveros, INTSOY University of Puerto Rico, has conducted studies with weed competition in soybeans. His research is funded under grant AID/CM/ta-g-73-50. His work confirms previous reports that full weed competition past the third to fifth week of soybean growth causes the highest reduction in soybean yield. Observations from his field studies suggested that prolonged weed competition also reduced the amount of nodulation. A cooperative study with Dr. Riveros was performed to investigate this hypothesis.

Treatments of inoculation and no inoculation were each established with weeding schedules beginning 1, 2, 3, 4 and 5 weeks after planting and also a treatment that was not weeded.

Plants were sampled 28 and 76 days after planting for plant growth and nodulation evaluations.

In general, there was a plant response to inoculation with the plant weight of the inoculated treatment being heavier than its respective uninoculated treatment. The response to inoculation comes from the fact that at the first sampling date the uninoculated treatments had less than 1 tap root nodule and less that 3 total nodules, whereas the inoculated treatments averaged 13.2 tap root nodules and 24.6 total nodules per plant. This same response to inoculation was also observed at the second sampling period, in spite of the fact that the average nodulation with the uninoculated treatments had increased to 2.1 tap root and 59.7 total nodules per plant. At the same time the average nodulation with the inoculated treatments increased to 14.0 tap root and 125.3 total nodules per plant. This response to inoculation, resulting in an increased nitrogen supply (average plant tissue nitrogen equal to 3.03% with uninoculated and 3.99% with inoculated), is also observed with seed yield. Uninoculated plots averaged 1966 Kg/Ha and inoculated plots averaged 2508 Kg/Ha.

In this study no consistent trends relating soybean nodulation to levels of weed competition were observed. The site utilized established

section 7 days later to provide a sampling for this section 27 days after emergence. This provides for a sampling of both sections at 27 days after emergence and 32 days after planting.

The nodulation data is all that has been collected, but been statistically analyzed. Comments will therefore be made in reference only to the raw nodulation data.

There appear be three factors influencing the amount of tap root and total nodulation in this study. The first factor is the type of inoculant. Examining the types of inoculant in Table 4 reveals that the granular inoculant provided the most tap root and total nodules at both the x and 10x rates under both irrigated and non-irrigated conditions. The second best treatment over all conditions was the liquid soil inoculant applied in the furrow. The remainder of the liquid soil inoculant treatments provided less nodulation and would be highly questioned as successful inoculants under these conditions.

The second factor influencing the amount of nodulation is the rate of applied inoculant. This is observed by comparing all inoculants, under either irrigated or non-irrigated conditions separately, and noting that in nearly every instance there was more tap root and total nodulation with the 10x rate when compared to the standard rate (X). This is in agreement with the previously reported study concerning rates of applied *R. japonicum* and shows that higher rates of applied rhizobia in new soybean fields result in more nodulation. This has been true within the evaluated range of applied rhizobia up to 3,900,000,000 *R.*/cm.

The third factor influencing the amount of nodulation is the difference between the irrigated and non-irrigated conditions. In all but one instance there is more tap root and total number of nodules at either the x or 10x rates when comparing the irrigated with the non-irrigated treatments. There was no rain for the first week after planting, while water was applied twice to the irrigated section.

Recorded soil temperature and moisture conditions indicate that the soil was hot and dry in the non-irrigated section which provided stress conditions on the applied rhizobia presumably reducing their population, but in fact reducing the amount of nodulation.

This study illustrates the need for a high population of applied rhizobia when inoculating soybeans planted in a tropical soil for the first time. A rate at least equal to granular soil inoculant would be recommended for normal conditions and if the inoculant were to encounter a stress condition in the soil even higher rates may be required.

The granular soil inoculant appears to provide protection for the rhizobia applied to a tropical soil, for equal numbers of applied

of Puerto Rico on an acid soil (Corozal clay - Ultisol) with a pH of 4.7 and high available aluminum.

The objective was to evaluate these varieties on the acid - high aluminum soil, which is common in the tropics. The plots were split to receive nitrogen fertilizer and granular soil inoculation to evaluate these two sources of nitrogen (nitrogen fertilizer and symbiotic nitrogen fixation). Treatments were replicated twice for observational purposes.

Plants were dug from the inoculated treatments 43 days after planting for nodulation counting. The commercial 4 strain granular soil inoculant produced very good nodulation on all varieties, even with the pH of 4.7. Tap root nodulation per plant ranged from 4.2 to 19.8 with an average of 13.6, while total number of nodules per plant ranged from 17.9 to 98.9 with an average of 55.9.

Yields were obtained and indicate some interesting responses. First, seed yields overall were very good (ranging from 1703 to 4750 kg/ha and averaging 3148 kg/ha) indicating a potential for soybean production on acid - high aluminum soils in the tropics. In general the varieties in this trial rank in approximately the same order for yield as is reported in the Fourth Report of Results - ISVEX, for soybeans grown in environmental zone IV (11 - 20° latitude and 0-500 m altitude). Davis, Calland, Cobb and Bragg are among the top yielding varieties with Williams and Improved Pelican among the lower yielding group.

In both ISVEX A and B trials, the yield for nearly all varieties supplied with nitrogen fertilizer and not inoculated yielded more than when inoculated and not nitrogen fertilized. This would suggest that on this soil the combined ability of the symbiotic nitrogen fixing system plus the available nitrogen from the soil was not capable of supplying the required nitrogen for maximum yields. However, an observation was made in this trial during the leaf senescence and maturing stages. Nearly all varieties began leaf senescence and the maturing process earlier when inoculated than when supplied with nitrogen fertilizer. This continued with, in general, the inoculated plants maturing earlier than when the same variety received nitrogen fertilizer. This indicates that a physiological plant difference existed in the nodulated plant when compared to the nitrogen fertilized plant.

Studies are planned to further investigate this observation and to consider the phosphorus response and interaction on this acid - high aluminum soil.

<u>International Soybean Rhizobium Inoculant Experiment (ISRIE)</u>. The International Soybean Rhizobium Inoculant Experiment (ISRIE) is a trial offered by INTSOY and will be made available upon request to ISVEX cooperators. ISRIE is intended to be an optional supplement

Attached to the sample is a temperature indicating label which irreversibly changes color when each of the following temperatures are met: 36°, 43°, 49° and 54°C. Instructions accompany the sample directing the cooperator to complete a data sheet, indicating which temperature has changed color, and to return the sample to the INTSOY microbiology lab at the University of Puerto Rico, Mayaguez, Puerto Rico. The maximum temperature under which the inoculant was exposed will be recorded and *R. japonicum* numbers and percent moisture determined

This trial is in coordination with the ISVEX trial. The instruction sheets, data sheet and inoculant sample are being included in the top of the box of seed being sent to all ISVEX cooperators from the University of Illinois.

Appreciation is also expressed to the Nitragin Co., Inc. for cooperation in preparing the samples of granular soybean inoculant utilized in this trial.

End of Project Status of Objective 2. A collection of *Rhizobium japonicum* strains has been assembled and is being maintained at the INTSOY microbiology laboratory in Puerto Rico. Research on ability of *Rhizobium japonicum* strains to survive at elevated soil temperatures found in much of the tropics and subtropics showed that the strains tested vary widely in ability to grow at temperatures above the determined optimum of 30°C. Investigations continue on the rates of *Rhizobium japonicum* needed in inoculum to economically produce nodulation. Inoculation rates equal to granular soil inoculant produced nodulation and seed yield greater than that obtained with inoculating rates approximating a standard seed applied inoculant. In the search for appropriate alternatives to peat as a carrier for the tropics, it appears that treated coir dust may equal peat. Although coir cannot be so finely milled as other alternate carriers it has higher organic content and moisture holding capacity than peat. An alternative method for sterilizing plant containers used in Rhizobium quality control and research work was developed. Using methyl bromide gas as a sterilizing agent the method employs lower level technology and energy requirements than the traditional use of an autoclave. Two new trials, to accompany the ISVEX trials, will provide further information on the granular soil inoculation method that has shown promise in Puerto Rico experiments and on the effects of international shipping and storage conditions on the quality of soybean inoculants.

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

Several 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

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

1. To compile the literature of soybean related arthropods and to establish a bibliographic data base 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.

4. To compile and publish comprehensive bibliographies on key soybean insect pests.

5. To provide copies of documents in the collection to researchers working in centers without library facilities.

6. To assist researchers in special literature searches for information not covered by the data base.

The Center compiles, searches and retrieves printed documents such as monographs, journal articles, scientific papers, reports, conference proceedings, dissertations, theses, etc...on anthropods associated with soybeans, including phytophagous species, vectors of soybean diseases, beneficial and incidental species which are part of the various soybean ecosystems around the world. Bibliographic citations and key word descriptors are stored in magnetic tapes for computerized storage and retrieval. Copies of the documents are filed at SIRIC.

Routine operations consist of continuously checking the current literature published internationally, obtaining copies of the relevant documents for processing and inputting references to computerized files.

Exhaustive searches have been made on insect species of economic importance in soybean production. Five bibliographies were published under the title "The Literature of Arthropods Associated with Soybeans": I. A bibliography of the Mexican bean beetle Epilachna varivestis (Mulsant); II. A bibliography of the southern green stink bug, Nezra viridula (Linnaeus); III. A bibliography of the bean leaf beetles, Cerotoma trifurcata (Forster) and C. ruficornis (Olivier); and IV. A bibliography of the velvetbean caterpillar Anticarsia gemmatalis (Hubner). The fifth bibliography was published in late 1978. This bibliography covers two Heliothis species: Heliothis zea (Boddie) and H. virescens (F.). These are considered 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 on these species. The bibliography should have great interest to soybean researchers as well as to those interested in pest management in general. Compilation of papers included in the bibliography was completed through June 1978.

research. Upon completing the Heliothis bibliography another project was initiated to make SIRIC's reprint collection as complete as possible. Rather than emphasizing individual insect species independent of their crop associations, strict concentration is being given to soybean (plus arthropod) literature. The goal is to bring the collection up to date with significant representations from the Japanese, Indian, Korean, and Russian literatures. Another small project initiated in 1979 involves the exchange of publications with institutions in the People's Republic of China where soybean entomology research is being carried out.

SIRIC is preparing to enter a new phase of operations characterized by maximum exploitation of its capabilities and interaction with other data bases. To achieve this a new series of programs are being planned that will accomplish the following goals: (a) more rapid and less expensive searches, (b) production of quality printouts ready for photoreproduction thereby reducing substantially the costs of printing bibliographies, and (c) completing the search of the soybean specific entomology literature and storing this literature in a separate file for time-sharing computer terminal input, and improvement of the code descriptors thesaurus.

IRCSA

The International Reference Collection of Soybean-Associated Arthropods (IRCSA) stores specimens and associated ecological data of quantitative samples of arthropods from all soybean-producing areas of the World. The collection along with its associated services is a joint project of the Illinois Natural History Survey; and the Illinois Agricultural Experiment Station. To date, some 150,000 identified specimens of about 2,500 species of soybean-associated insects and other arthropods have been accessioned. IRCSA is fully computerized, and its data are accessible through automated retrieval programs. Because of the recent inception of soybean production in geographically remote and biologically little known areas of the World (e. g. Bolivian and Peruvian Amazonia), IRCSA in both its research and service functions operates on the leading edge of systematic knowledge concerning many pest species of such areas.

The purposes of IRCSA are fourfold:

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.

a long-term project to monitor the colonization of soybeans in El Salvador, where soybeans have recently been introduced on an experimental basis, has been initiated in collaboration with a researcher in that country. In addition to these works, analyses of the total soybean-associated arthropod faunas of Brazil, Colombia, and Mexico are underway.

In its relatively short existence, IRCSA has evolved into the pre-eminent source of information regarding the soybean-associated arthropods of the World, and it has achieved international recognition. Future efforts will be focused upon the expansion and consequent strengthening of that position in order to better serve those concerned with crop protection wherever soybeans are grown.

Soybean Economic Outlook. World soybean production and trade have changed rapidly in the past several years and major changes are expected to continue through the remaining years of the 20th century. World population, income, and diet pattern changes have resulted in expansions of soybean demand and consequently changes in prices, production and trading patterns. To better understand these recent changes economic research was initiated in 1978. Information is being gathered for modeling projections of soybeans in the world agricultural picture and attention is being given to the economics of various levels of processing operations.

World soybean production has been increasing at 7.7% per year between 1972/73 and 1977/78 - one of the most rapid increases of a major agricultural commodity over a comparable time period. As one of the most geographically concentrated commodities grown, 90 percent of the world's production is concentrated in the U.S. (65%), Brazil (13%) and China (12.8%). However, this concentration of production among these large producers has declined in the past six years from 94 percent in 1972/73.

Soybean production in less developed countries is difficult to analyze since small production volumes are often included in "other" categories of world agricultural statistics. From information developed, it appears that the total volume of output of soybeans in less developed countries (excluding China) has been increasing at about 5 percent per year from 1972/73 through 1977/78 and accounted for about 3 percent of the world total in 1977/78. If China is included in the total, LDC's account for over 15 percent of the world production. Soybean production in less developed countries other than China is concentrated in Asia with 72 percent and Latin America with 24 percent of the total LDC production. Africa accounts for only 4 percent of this total. The current largest producers among LDC's are Indonesia, South Korea, Paraguay, North Korea, Thailand, and India. Production has been increasing most rapidly in Bolivia, Ecuador, Paraguay, Egypt, India, South Korea, and Thailand.

The extent of the growth in demand for soybeans for direct consumption is difficult to assess since very little information is available. Given the large quantities of soy meal and oil projected to move through international markets, soybeans for direct consumption will not be a major percent of total world trade but may be important in specific countries where product development work is developed.

Real soybean prices are projected to increase through the year 2000. This reflects the expected strong demand for soy products as income levels increase and the projected smaller increases in production after 1990. This projection is contrasted to slower rising projected corn and sorghum prices, for example. Therefore, a glutted soybean market is not projected. However, soy oil prices may face downward pressure on world market as oil supply is projected to more than double by 2000. Given what appears to be slower demand increases for soy oil, double current production levels, and an approaching saturated oil market, the year 2000 may see very low oil prices.

Current conditions in the world soybean market and country development programs are causing several nations to consider importing raw beans to be processed internally. The economic evaluation of these decisions hinges on the amount and mixture of internal demand for soy products, processing economies of size, internal production levels, and soybean versus meal and oil international transport costs. Countries planning to develop soybean processing capabilities must either erect import barriers or face competition from exports of large scale processing plants in developed countries. Modern soybean processing plants involve substantial capital, technical expertise, management competence and large quantities of various inputs. This process of transforming soybeans into meal and oil involves substantial economies of size particularly up to 1000 tons/day. When located in a developed country costs of processing soybeans in a 500 ton/day plant are approximately twice as high as processing the beans in a 2000 ton/day plant. However, in less developed countries where relative prices of labor and capital are different, the comparative advantage of a large versus small solvent extraction plant is less. To survive and compete effectively in the meal and oil market with large developed country processing plants, LDC's need to make up the processing cost disadvantages of smaller plants with lower raw soybean ocean transport costs relative to meal and oil ocean transport costs. Research is being done to ascertain the extent of this difference.

Products from solvent extraction plants need not be soy meal and oil only. High calorie soy oil is usually produced, but the meal residue may be used for high protein baking ingredients and additives, cereal products, beverage powders and numerous other products for use as human food. With the large soy oil imports by LDC and their need for higher protein diets, demands for soy products derived from solvent extraction plants might be quite high in specific countries where soybean production is developing. A small 500 ton/day plant

community to be added to the free subscription list have increased the size of the list to over 2,000, with more than two-thirds of the mailings going to overseas addresses. A recent readership survey will be used to refine the subscription list to better direct the information to those who can benefit most from it.

INTSOY Publication Series. An important means of disseminating research information to a broad-based audience has been the INTSOY Publication Series. Initiated from contract sources the series has greatly enhanced the joint UIUC and UPR/MC soybean response capability as well as providing a means of making research results readily available to those interested in tropical and subtropical production and use of soybeans. Seventeen publications have been prepared since early 1974.

Number 1--Selected Literature of Soybean Entomology--George L. Godfrey, Editor: April 1974.

Number 2--Proceedings of the Workshop on Soybeans for Tropical and Subtropical Conditions. May 1974.

Number 3--A Case Study of Expeller Production of Soybean Flour in India--S. W. Williams and K. L. Rathod. April 1974

Number 4--Soybean Processing in India: A Location Study on an Industry to Come--Matthias von Oppen. July 1974.

Number 5--Potential Production of Soybeans in North Central India--S. V. Williams, W. E. Hendrix, and M. K. von Oppen. August 1974.

Number 6--Soybean Production, Protection, and Utilization--Proceedings of a Conference for Scientists of Africa, the Middle East, and South Asia--D. K. Whigham, Editor. March 1975.

Number 7--An Annotated Bibliography of Soybean Diseases--J. B. Sinclair and O. D. Dhingra. December 1975.

Number 8--International Soybean Variety Experiment, First Report of Results--D. K. Whigham, October 1975.

Number 9--Soybean Cultivars Released in the United States and Canada; Morphological Descriptions and Responses to Selected Foliar, Stem and Root Diseases--Compiled by T. Hymowitz, S. G. Carmer and C. A. Newell. January 1976.

Number 10--Expanding the Use of Soybeans, Proceedings of a Conference for Asia and Oceania--R. M. Goodman, Editor. December 1976.

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

Scientists in plant pathology and entomology cooperate extensively on addressing the problems of disease control in soybeans. There are two major thrusts to the work under this objective: 1) soybean seed quality, pathogens and fungi and 2) epidemiology of soybean mosaic virus (SMV), the latter featuring cooperative research between pathology and entomology.

The problem of seed quality is a complex one, involving harvesting, storage and planting practices. Soybean seeds are vulnerable to a wide range of decay organisms, organisms that delay germination and emergence, and soilborne pathogens that restrict the growth of plants throughout the season. All of the microorganisms in this desease complex can have a direct or indirect effect on yield and the resulting seeds from the affected crop. The quality of the seed not only is important in planting seeds, but it affects the quality of products derived from infected seeds as well as when used as feed for animals. Seeds carry microorganisms from one season to another and from one location to another.

During the three years of this contract, research has been conducted to define some of the pathological problems affecting soybean seed quality in the field and in storage; how they affect oil and flour; and to study possible means of controlling them. Principal pathogens and fungi studied were Bacillus subtilis, Phomopsis sojae, Cercospora kikuchii, Colletotrichum dematium var. truncata, Macrophomina phaseolina and Aspergillus flavus.

Bacillus subtilis is an ubiquitous bacterium, often considered as a contaminant in microbiological work. Its constant association with soybean seeds was thought to be of this nature. However, through indirect evidence and from data obtained from this project, it was found to be a major pathological factor involved in seed decay under conditions of high moisture and temperature. It was reported from several tropical countries, including Egypt, Nigeria, Ivory Coast, the Philippines, and Indonesia that obtaining a stand of soybean planted in soil with a high temperature (35 ± 3C) was difficult. For example, at IITA, Nigeria, not a single seed emerged from a large variety trial when planted in moist soil over 35C. B. subtilis was involved.

In cooperation with scientists at the University of Puerto Rico, Mayaguez, the role of microorganisms in the deterioration of soybean seeds stored under tropical conditions was first reported. It was shown that microorganisms, particularly, B. subtilis, can cause serious problems. With the beginning of soybean production in the tropics, the development of proper storage conditions for the crop is an important consideration.

Symptoms of charcoal rot, pod and stem blight, anthracnose and other fungi usually appear when soybean plants are under stress from environmental conditions or due to infection of soybean mosaic virus. Often these diseases are most evident near the end of the growing season when soybean plants begin to senesce. Using Paraquat, a harvest aid herbicide, a method was developed to detect the latent infection of these and other fungi before symptoms appear. This technique can be of great benefit to breeders as well as pathologists. Breeders can test for disease susceptibility before soybean plants mature. Pathologists can use the technique to determine the level of infection in the field and be able to determine whether a fungicide should be used to protect seeds from infection, as well as study the epidemiology of the fungi involved. The technique is simple and can be used in laboratories in developing countries.

Two major approaches have been taken to the control of seedborne microorganisms of soybean: nonchemical and chemical. Good quality soybean seeds harvested at the precise time of maturity, dried to approximately 13% moisture, stored in a cool environment will provide excellent seeds for planting or processing. When these conditions cannot be met, seed treatment with a fungicide and/or antibiotic, or the use of foliage sprays can reduce the effects of seedborne fungi on seed quality. The details of the seed treatments that have been studied and the foliage fungicide spray schedules used are presented in annual reports. Many of the more common fungicides are available in developing countries, but may be difficult to obtain for individual growers or farmers may not be educated in their proper use.

One of the major constraints of soybean production in the Far East is soybean rust (Phakopsora pachyrhizi). INTSOY held a soybean rust workshop in Manila and developed a program of research and outreach. The U. S. Department of Agriculture has provided grants for study of the disease in Australia and at AVRDC, Taiwan. INTSOY published the proceedings from the Manila conference, which provided the first comprehensive review of the subject. Because of the "rediscovery" of the pathogen in the Caribbean and Central America, USDA has taken a lead role in monitoring the disease in this hemisphere.

The focus on seed pathology has had significant influence on the establishment and development of seed pathology studies internationally. An important event was the First Latin American Seed Pathology Workshop held in Londrina, Brasil, in 1977. The proceedings of the Workshop are significant in that information not previously published in such comprehensive form on techniques of detecting seedborne fungi and bacteria are included. An Inter-American Working Group of Seed Pathologists was formed to plan additional research in seed pathology and committees on seed pathology have been established in two professional societies, the American Phytopathological Society and the International Society of Plant Pathology.

highly virulent strains of SMV, one of which infects all of the SMV-resistant cultivars with which it has been tested. These highly virulent strains of the virus, 4 of 7 of which were previously unknown, originated from Asian accessions. Reactions to these strains result in severe reductions of the number of pods and seeds produced in plants that survive the acute stage of infection, and sometimes in plant death. Necrotic reactions of this sort are not a laboratory curiosity. In Korea such severe reactions by a supposedly SMV-resistant cultivar to field infection by a virulent strain of the virus is a major limiting factor in soybean production.

Results of this study lead to the conclusion that the various sources of SMV resistance in soybeans probably are due to more than one genetic system in the plant. The various cultivars used as differentials in these tests reacted differently to different strains, indicating genetic differences which may be usefully manipulated to create more broadly resistant cultivars. These strains are now in use in the INTSOY breeding program reported under Objective 1.

4. Effect of SMV on certain seed characters: Three soybean lines that were previously shown to seed transmit the Illinois Severe isolate of soybean mosaic virus (SMV-Il-S) at high rates were used to determine whether a particular isolate of SMV would influence certain seed characteristics. If the soybean lines performed the same when they were infected with different SMV isolates then a single representative isolate could be used in breeding and research. The seed characters under consideration were the weight of 100 seeds, the percentage of the seeds showing mottling, the percentage seedling emergence and the percentage seed transmission. Significant differences in performance were found between isolates for mottling, seed emergence and seed transmission but not for 100 seed weight.

5. Effect of SMV on leaf dry mass, yield and seed quality: Timing of SMV inoculations was found to be highly correlated with leaf dry mass and leaf area, yield, and seed quality of soybeans. In general, the earlier the inoculation, the greater the reduction in these components.

The transmission of SMV in the field by a transient population of winged aphids and the probable dominant role of virus-infected seedlings arising from infected seeds as source plants for virus spread within the field, necessitate an understanding of the impact of virus infection on yield components as a function of growth stage at the time of inoculation. The results of this study show the high degree of correlation between time of inoculation and yield, seed quality, and several of the more

7. Multiple or secondary spread within soybean fields: It has been shown previously that the most important primary sources or reservoirs of SMV, at least in Illinois, are seedling soybeans containing seedborne virus. Through time, aphids transmit the virus from these primary sources to other soybean plants in the area (primary spread). After a brief latent period within the new host, the virus is able to be transmitted to other plants. At that time the infected plant is termed a secondary source. This process, theoretically, can continue throughout the season. The implications of such a model suggest exponential increase of spread through time. In 1978 attention was given to the number of times during a growing season the virus can be transmitted from plant to plant. Secondary spread took place within 60 days of mechanical inoculation of SMV in alternate rows of a field plot. There was no tertiary spread, however, probably due to a drastic reduction in aphid flight activity for a two week period and the presence of a relatively few tertiary source plants.

8. Correlating aphid flight behavior with field spread of SMV: A 1976 study provided valuable information on several aspects of SMV epidemiology; a) the amount of spread away from a point source of infection could be determined, (b) the effect of wind on the spread patterns of SMV was pronounced, and c) the timing and abundance of the major vector species correlated well with the increase in spread of SMV.

   In 1978 a study was conducted to examine the capacity of various aphid species to spread SMV in the field by periodic planting and roguing of monitored plots of soybeans of about the same age. Planting and virus inoculation dates were timed so that monitoring could be conducted in a continuing sequence through the season. The amount of spread of SMV was positively correlated with aphid flight activity. The greatest spread occurred when aphid populations were very high indicating that SMV can be rapidly spread by aphid vectors. During the period of reatest spread the most abundant aphids were *R. maidis*, a known vector, and *Wyzocallis asclepiadis*, heretofore not known as a vector. Additional laboratory tests to confirm *M. asclepiadis* as a vector will be conducted in the coming year.

   The experiment demonstrated that a) aphid vectors are capable of transmitting SMV throughout the growing season in plantings of young soybeans and b) the monitoring experiment has demonstrated that such a procedure can help isolate aphid species as candidate vectors of importance in the field. The transfer capabilities of employing this type experiment in LDC's is great with potentially high benefits in understanding causes of virus epidemiology. This tool will assist researchers in LDC's to better understand the mechanisims of virus epidemiologies under their conditions and determine appropriate control strategies.

Plans to address the serious problem of soybean rust in Asia were formed in collaboration with workers in that area, and the "rediscovery" of the disease in this hemisphere underscores the need for more information on the nature and potential for control of the disease.

A number of studies on the epidemiology of soybean mosaic virus (SMV) added to the sum of knowledge about this important soybean virus. A program has been developed to produce virus-free seeds in Nigeria for distribution to cooperators in Africa. Studies have been made and are continuing on the identification of SMV strains prevalent in various LDC's, their biological properties and their transmission by seed or insect vector. Basic genetic research on bean golden mosaic virus (BGMV) established that it was the first plant virus with a single-stranded DNA genome.

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

Substantial effort was made in developing methods to trace and predict aphid movement in order to determine appropriate control measures to reduce the spread of SMV by aphids. A concurrent focus considered the role of phytophagous thrips in soybean production and the development of control methods.

Everywhere that soybeans grow, alate aphids form a part of the soybean community. Regardless of aphid colonization potential, an independent assessment of numbers and kinds of aphids flying over and, more importantly, landing in soybean canopies is of importance to growers and extension personnel because several species of aphids are active vectors of several types of viruses that affect soybeans. Yield loss data vary depending on many factors, but reductions resulting from natural infections by soybean mosaic virus of up to 95% have been reported.

A search of the literature disclosed no satisfactory technique for monitoring aphid activity. The type of trapping device needed would measure absolute landing rates of all species of aphids on soybean canopies. Traps currently in use give skewed readings with respect to aphid species abundance (e.g. yellow pan traps) or skewed readings with respect to absolute densities (e.g. vertical cylindrical traps). It was, thus, thought important to devise a trap that would meet the needs of our project, and would also serve as a model for sampling aphids as plant virus vectors in other crops.

A trap was designed to give absolute records of all aphid species alighting on a canopy and had the following properties: 1) horizontal attitude, 2) position over and relatively close to canopy top, and

Pest management research activities initiated in Illinois and Puerto Rico are used to test methodologies that, if found to be sound and practical, can be used on farms in the tropics and subtropics. The 1976-77 annual report mentioned the adaption of techniques developed under a previous research contract by the Brasilian state of Parana. During the period of the current research contract several additional pest management studies have been undertaken or planned. They include:

1. El Salvador. Rate of change in species composition of a soybean field from season to season. Begun 1976. Detailed records of a seasonal trends in population structure of all insect species in soybean fields to be maintained until 1981, at which time analysis will be made. Information will result in basic predictive capability with insect pests attacking soybean in areas where soybean is introduced.

2. Ecuador. Soybean mosaic virus and its spread in seed fields. To begin in 1980. To test performance of living barriers and their reduction of SMV spread by aphids.

3. Colombia. Leafhopper pathogens affecting soybean. In planning stage. Purpose is to understand the causal agent, spread patterns and methods of control of leafhopper.

4. Peru. Phenology and population dynamics of soybean associated arthropods in the high selva. Begun in 1979. Purpose is to establish existence in baseline levels of insect pests and beneficials, to understand basic population fluctuations of various species throughout the soybean growing season and to link these dynamic aspects with various growth stages of the crop.

5. Peru. Supervised monitoring of insect pest populations in soybean fields of the high selva and initiation of a pest management program. To begin in 1979. Purpose is to establish a baseline insect pest management program, to initiate a supervisory system for monitoring insect pest increases and declines in grower fields, to provide current chemical control recommendations for insect pests when they exceed economic thresholds, and to acquaint soybean growers with the concept and practice of pest management through supervised control procedures.

6. Peru. Soybean mosaic virus and its field spread by aphids. To begin in 1979. Purpose is to determine whether or not SMV is transmitted in coastal areas, to determine amount and rate of spread expected in a growing season from a small point source and to determine if sunflower barriers reduce field spread significantly.

7. Peru. Biology, ecology and economic importance of a cerambycid stem borer, *Grammopsoides rufipes*, on soybeans in north coastal areas.

Soybean seed does not store well as compared to other legumes. The major environmental factors influencing seed deterioration are temperature and moisture. Moisture is usually considered in terms of seed moisture content. Since seeds lose or gain moisture from the surrounding air until reaching equilibrium at a given set of conditions, it is also appropriate to think of moisture in terms of the relative humidity of the storage environment. Storage fungi are a major cause of reduced germination in soybeans, especially when soybean seed is stored at moisture contents above 12.5 percent.

The results showed that the viability of high quality seed declined rapidly to almost zero after nine months of improper storage in a tropical environment. The loss of seed viability appeared to be closely associated with a marked gain in seed moisture during storage. Containers resistant to moisture vapor transmission tended to preserve seed quality. Drying soybean seed to a safe moisture content was shown to be of little value if no effort was made to prevent moisture gain during storage. The moisture content of unprotected seed approached equilibrium with the humid atmosphere of the tropical environment. Reducing the seed moisture content and maintaining it during storage were shown to be essential ingredients for preserving seed quality at an acceptable level for nine months storage in the tropics. Sealed metal containers or plastic bags placed in metal containers with covers offered adequate storage protection for seed with a low initial moisture content.

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 see Insulation also had no effect of practical significance. Parallel sealed can storage tests in Urbana (25°C [illegible] 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.

<u>End of Project Status of Objective 6</u>. Cooperative research at UIUC and UPR/MC evaluated tropical storage properties of soybean seed.

boiling water and the beans were boiled for ten minutes. After boiling, the water mixture was ground in a Waring blender. The ground slurry was simmered for an additional 20 minutes after which sufficient water was added to replace that lost by boiling and the slurry was filtered. The filtrate or milk was flavored by the addition of sugar, salt and diacetyl or vanilla.

Cracked or broken raw dry beans and powdered raw dry soybeans were also used to prepare the soymilk. A comprehensive organoleptic evaluation of the soy milks prepared from the three types of soy raw materials showed no significant differences in organoleptic properties with these exceptions. Color scores were significantly (5 percent level) higher for the soy milk prepared from the powdered, dry, raw soybeans. Flavor and mouth drying characteristics of beverage prepared from powdered soybeans were significantly (5 percent level) inferior to beverages prepared from whole or cracked beans. However, all scores were in the range of 7 on a hedonic scale of 9 which indicated good acceptance for all products. The procedure is considered ready for further testing and improvement under conditions in developing countries.

Evaluation of Filtering Concepts for Village Level Preparation of Soy Beverage. Three systems were developed for filtering soy slurries in preparation of soy milk. These were a simple filter sock or bag, a cradle filter and a basket centrifuge. These filtering devices were thoroughly tested using soybean slurries made from whole, cracked and powdered soybean. These tests showed that soy milks prepared from the three different raw soybean types were quite similar with respect to yield, percent protein, solids and sediment. Comparison of the soy milks prepared with the different filtering devices showed that the centrifuge produced the highest yield of milk, followed by the sock and cradle methods. However, the sediment content of the milk filtered with the sock method was invariably much lower than that from the centrifuge or cradle. When all factors were considered, the sock filter was judged to be the most desirable method. This method employs the lowest level of technology and is by far the cheapest and easiest to manufacture.

Evaluation of Mill for Grinding Dry Soybeans and Various Cereal Products. A Decker Grainmaster hammermill was purchased for $704.00. This price included three mill screens and was the lowest priced hammermill in about sixty quotations from suppliers. This mill was tested using dry soybeans, corn and soybean-corn mixtures. The mill performed acceptably and was found to be satisfactory for grinding dry raw soybeans for soy beverage preparation. This type of mill is recommended for installation as a cooperative utility for village use.

Development of a Device for Separation of Hulls from Cotyledons. A device was designed, constructed and tested for the separation of hulls and cotyledons from dehulled whole dry soybeans. Thorough testing

E. Administration, Staff and Budget

The program is 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, Office of International Agriculture, and the Office of International Programs and Studies.

At the end of the report period the Directorate and professional group numbered 9.9 full time equivalent staff. They were assisted by 9.75 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 57, 58, 59 and 60.

Funds for project operations of the contract were adequate and provided in a timely manner. Summary of expenditures for the life 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	Actual Exp. 4/1/78-3/31/79	Total Exp. 4/1/76-3/31/79
1. Salaries	$214,225	$274,648	$398,353	$887,226
A. Professional	(103,250)	(146,857)	(205,302)	(455,409)
B. Support	(110,975)	(127,791)	(193,051)	(431,817)
2. Fringe	21,740	27,298	45,784	94,822
3. Indirect Cost	141,390	179,133	225,364	545,887
4. Travel & Transportation	42,280	38,349	34,925	115,554
5. Other Direct Costs	31,205	50,897	51,295	133,397
6. Equipment & Supplies	28,875	62,415	79,418	170,708
	$479,715	$632,740	$835,139	$1,947,594

INTSOY Project Staff
Assigned to Research Contract AID/TA-C-1294
April 1, 1976- March 31, 1979

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)	.50
Dunker, R. E.	Asst. Agronomist	Agronomy (to 10/20/76)	1.00
Ferrier, L. K.	Asst. Professor	Food Science (to 10/5/77)	.75
*Goodman, R. M.	Assoc. Professor	Plant Pathology	.75
*Hill, H. J.	Asst. Agronomist	Agronomy (from 12/1/76)	1.00
Hittle, C. N.	Professor	Agronomy (4/1/76 to 7/9/76)	.25
*Irwin, M. E.	Asst. Professor	Ag. Entomology	1.00
*Jackobs, J. A.	Professor	Agronomy (from 8/21/78)	.50
*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 (8/21/77 to 6/20/78)	.25
*Nguyen, Q. N.	Asst. Professor	Agronomy (from 11/13/78)	1.00

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Name	Rank/Title	Department	FTE
B. Support Staff (con't.)			
*Brinkman, G. S.	Res. Assistant	Plant Pathology (from 5/21/76)	.50
*Burnsmier, Helen	Clerk III	Agronomy (to 9/30/78)	1.00
*Cunningham, Patricia	Clerk-Typist III	INTSOY Administration (1.00 to 9/16/78)	.75
Eckenbeck, Susan L.	Res. Assistant	Agronomy (7/21/76 to 10/31/77)	.50
*Elmore, R. W.	Res. Assistant	Agronomy (from 8/21/78)	.50
Endsley, Margaret R.	Clerk-Typist III	Agronomy (to 9/27/77)	1.00
Foor, S. R.	Res. Assistant	Plant Pathology (4/1/77 to 7/20/77)	.50
*Halbert, Susan E.	Res. Assistant	Ag. Entomology (5/21/76 to 12/20/78)	.50
Kanthamani, S.	Res. Assistant	Food Science (to 11/23/76)	.25
*Kogan, Jenny	Res. Assistant	Ag. Entomology (from 1/21/77)	.25
*McBroom, R. L.	Res. Assistant	Agronomy (from 8/21/78)	.50
*McClary, Richard D.	Res. Assistant	Plant Pathology (9/21/77 to 12/20/78)	1.00
McCune, T. D.	Res. Assistant	Food Science (to 8/20/76)	1.00
*Medina-Lopez, F.	Res. Assistant	Ag. Economics (from 7/1/78)	.50
Newell, Christine A.	Res. Associate	Agronomy (to 8/20/77)	1.00

APPENDIX
LIST OF PUBLICATIONS
EMANATING FROM WORK DONE UNDER
CONTRACT AID/TA-C-1294

1. Aminlari, M., L. K. Ferrier, and A. I. Nelson. 1977. Protein dispersibility of spray-dried whole soybean milk base: Effect of processing variables. J. Food Sci. 42(4):985-988.

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

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4. Cerkauskas, R. F., S. R. Foor, and J. B. Sinclair. 1978. Effects of paraquat used as a harvest aid on soybean seed quality. Phytopathol. News 12:85.

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