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A GRANT TO STRENGTHEN THE INSTITUTIONAL RESPONSE CAPABILITIES OF THE UNIVERSITY OF PUERTO RICO IN CROP PROTECTION OF SOYBEANS FOR TROPICAL AND SUBTROPICAL AREAS

ANNUAL REPORT OF GRANT AID/CM/TA-G-73-50
OCTOBER 1, 1978 TO SEPTEMBER 30, 1979

SUBMITTED TO
THE AGENCY FOR INTERNATIONAL DEVELOPMENT
DEPARTMENT OF STATE
WASHINGTON, D.C.

BY
DEPARTMENT OF CROP PROTECTION
COLLEGE OF AGRICULTURAL SCIENCE
UNIVERSITY OF PUERTO RICO
MAYAGUEZ CAMPUS
INTERNATIONAL SOYBEAN PROGRAM, INTSOY

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Date Due: December 1, 1979

Date Submitted: January 1, 1980

A. Title Page

Grant Title: A Grant to Strengthen the Competence of the University of Puerto Rico in Disease Control and Related Insects and Cultural Practices of Soybeans and Other Food Legumes for Tropical and Subtropical Areas

Grantee: University of Puerto Rico, Mayaguez

Grant Staff: Dr. Paul R. Hepperly, Interim Director and Plant Pathologist
Dr. Raul Abrams, Associate Director, INTSOY
Dr. Nelia Acosta, Nematologist
Dr. Guillermo Riveros, Weed Scientist
Dr. Pedro Meléndez, Pathologist
Eileen Rosario, Research Assistant
Eduardo Riera, Laboratory Assistant
Rafael Ruiz, Laboratory Assistant
Maria Pagán, Administrative Secretary

AID Sponsoring Technical Office: TA/AGR

B. Statistical and Narrative Summary

1. Statistical Summary:

Period of Grant: September 16, 1973 to September 16, 1980
Amount of Grant: $837,676
Expenditures:
a) Report Period $194,638.50
b) Accumulated 694,638.50
c) Anticipated 143,000.00

2. Narrative Summary

For the period September 16, 1973 to September 16, 1978, the University of Puerto Rico at Mayaguez was granted $500,000 (AID/CM/ta-g-73-50) for developing its existing competence for research, teaching and extension in the area of crop protection of soybean and other grain legumes in tropical areas. A two year extension was granted for the period September 17, 1978 to September 16, 1980. From its inception, this grant has collaborated with the University of Illinois to develop an international network for the development of soybeans (INTSOY).

The University of Puerto Rico soybean program supports research in pathology, nematology and weed science. Grant personnel interact with the soybean breeder from INTSOY (University of Illinois) who is stationed in Puerto Rico. Through cooperation with the INTSOY breeder, genetic solutions are being sought for the pest problems occurring on soybeans in the tropics.

Grant staff belong to the Department of Crop Protection, University of Puerto Rico. This department fosters an integrated approach to pest management. Grant staff offer courses in Nematology, Mycology and Weed Science and are active in advising graduate students at the M.S. level.

As the only U.S. land grant institution with a tropical climate and ability to teach in Spanish, the University of Puerto Rico has an unique ability in international training and outreach. Program staff have participated in training and outreach activities in Brazil, Colombia, Costa Rica, Dominican Republic, Jamaica, Panama, Peru and Puerto Rico and have been involved in advising and teaching graduate students from Bolivia, Colombia, Ecuador, El Salvador, Guatemala, Honduras, Nicaragua, Panama, and Puerto Rico.

Numerous linkages with state, national and international organizations have been realized under this grant.

C. Detailed Report

Food legumes such as soybean (*Glycine max*), field bean (*Phaseolus vulgaris*), cowpea (*Vigna sinensis*) and pigeon pea (*Cajanus cajan*) are excellent sources of inexpensive high quality protein. Malnutrition affects an estimated 400 million to 1.5 billion people worldwide. The most common form of nutritional deficiency develops from insufficient protein. Protein is particularly necessary for children during periods of active growth. For humanitarian reasons and to ensure global stability, solutions to worldwide food shortages

must be sought.

Food legumes can be grown extensively in tropical areas where the majority of protein deficiency exists. Presently, yields of these are low due to unimproved production practices. A variety of pests (fungi, bacteria, viruses, mycoplasmas, insects, nematodes and weeds) reduce yields of grain legumes particularly under tropical conditions. Unless crop protection measures are developed and applied, increase of grain legume production in tropical areas is unlikely.

Grant objectives focus on the development and improvement of the University of Puerto Rico's institutional response capability in the area of tropical crop protection of soybean and other grain legumes. The development of background knowledge through research optimizes staff effectiveness in teaching and outreach.

Major objectives are:

I. Expanding the research base to solve crop protection problems on soybean and other grain legumes in the tropics.

II. Improving the University of Puerto Rico educational capability by utilizing expertise gained under the research program.

III. Increasing advisory capability by developing a coordinated, and interdisciplinary team of researchers with expertise in the protection of soybean and other grain legumes in the tropics.

IV. Expanding research and information linkages to stimulate increased production of soybean and other grain legumes in the tropics.

D. Accomplishments

A strong research program is needed to demonstrate problem solving and to gain the confidence of institutions in LDC's looking for training and consultation in crop protection of soybean and other grain legumes in the tropics.

I. Expanding the knowledge base for crop protection of soybean and other grain legumes in tropical areas.

a. Nematology (Dr. Nelia Acosta)

Two of the major nematodes which have been the center of soybean disease control programs in the United States are root knot and cyst nematodes. Of these, cyst nematodes (*Heterodera* spp. and *Globodera* spp.) are more adapted to temperate climates and *Meloidogyne* is more damaging in tropical or semitropical areas. As a part of INTSOY development of tropically adapted germplasm, root-knot nematode resistance is an important consideration. The nematodes fauna in tropical areas is not as well characterized as it is in temperate zones and damaging species need to be identified. Chemical and other control measures should be investigated to allow for optimal soybean production where adapted nematode resistant varieties are not available.

The objectives of the nematology component during the report period were: 1) to survey the soybean production area in Puerto Rico for phytopathogenic and other nematodes and to correlate some edaphic factors with nematode populations 2) to test the resistance of some of the varieties from the southern United States to endemic populations of *Meloidogyne incognita* from Puerto Rico and 3) to evaluate the efficacy of various granular nematicides for controlling nematode populations and for increasing soybean yield under Puerto Rico conditions.

1. Survey

Seventy-one soil samples were collected from soybean fields located at the Isabela Substation of the University of Puerto Rico. Data was taken on the species and numbers of nematodes present. The nematode numbers were correlated with (Ca, Mg, N, P, K), macroelement concentrations, soil organic matter (%), soil cation exchange capacity and pH. *Rotylenchulus reniformis* was the species occurring most frequently in the soybeans fields sampled. This species composed 81% of the total population and was present in 95% of the samples. Other nematodes consistently found in soil samples were: *Aphelenchus* sp., *Tylenchus* sp. and *Aphelenchoides* sp. which are mainly mycophagous.

No significant association was found between any soil factor and nematode population when correlation analyses was done. Mean values for the nematode population and other soil factor are given in Table 1.

2. Cultivar Reactions to Puerto Rico Root-Knot Nematode Populations

In the greenhouse, six commercial cultivars of soybean: Bedford, Bragg, Forrest, Hardee Late Selection, Hutton and Jupiter were inoculated with a population of *Meloidogyne incognita* derived from root-knot diseased

okra (*Albemoscus esculentum*) from Isabela. Ninety-six 12-cm plastic pots were filled with 700 cm^3 of sterile sandy loam soil. Half of the pots were not inoculated and served as control and the others were treated with 1,500 *Meloidogyne incognita* eggs per pot. Each treatment was replicated 8 times for each cultivar. Pots were completely randomized on the greenhouse benches. Forty-five days following inoculation, data was taken on root-knot gall index, total nematode population, fresh weight of shoots, and dry weight of roots.

Susceptibility of the tested soybean cultivars are given in Table 1. Hutton was found highly resistant while Bedford, Forrest and Hardee Late Selection were susceptible. Dunn (1) found Hutton, Bragg and Forrest (I) resistant to both cyst and root-knot nematodes. In our tests neither Bragg nor Forrest were found resistant to our population of *M. incognita*. Furthermore, Bedford which was found resistant by Hartwig and Epps (2) was highly susceptible in our test. These results emphasize the danger of generalizing cultivar reactions over the distinct nematode populations occurring in differing geographical locations without location and population specific testing. No significant differences in plant weights were observed between treatment during the short incubation of this test. From our results it appears that Hutton may have a generalized resistance to soybean nematodes and should be included for pest management programs.

3. Chemical Control with Granular Nematicides

The chemical control of indigenous nematodes at Isabela, Puerto Rico was tested with Williams soybeans. Four nematicides: ethoprop 10G, aldicarb 10G, fensulfothion 15G and phenamiphos 15G were applied at 16.8 and 33.6 kg/ha for the first two products and at 7.2 and 14.6 kg/ha for the last two, respectively. Chemicals were spread on the row at planting and incorporated to 15 to 20 cm of depth by hoe. Each treatment was replicated five times and arranged in a randomized complete block design. Nontreated plots served as controls.

The best control of nematodes was obtained with aldicarb (Table 3). A nonsignificant 7% increase of yield was found in Aldicarb plots at both application rates. Nonsignificant yield increases were found for fensulfothion at either application rate and nonsignificant yield losses were found for both doses of both Ethoprop and Pehnamiphos. The potential use of granular nematicide need further work on soybean to determine if and when they may be necessary

Table 1. Means of calcium, magnesium, nitrogen (ammoniacal and nitrate), % organic matter, phosphorus and potassium content and pH, cation exchange capacity and nematode population values from soil samples from soybean fields.

Elements and others	Means from 72 soil samples
Calcium	1692.2 mg/l
Magnesium	127.8 mg/l
Nitrogen (ammoniacal)	9.9 mg/l
Nitrogen (nitrate)	19.5 mg/l
Organic matter (%)	2.9 ---
Phosphorus	13.9 mg/l
Potassium	150.6 mg/l
pH	6.4 ---
Cation exchange capacity	11.8 meq/100g
Nematode population	524.1 nematodes/250 cm^3

Table 2: Comparison of root-knot incidence, total nematode populations per gram of fresh root of six soybean cultivars grown in soil infested with *Meloidogyne incognita*.

Host	Root-knot Index (0-5)[y]	Total No. Nematodes[x] (Root+soil)	Per gram fresh root
Bedford	3.8 a[z]	8191 a	6061 a
Bragg	3.4 bd	1460 a	479 a
Forrest	4.1 a	10394 b	8913 b
Harder Late Selection	3.5 ad	621 a	546 a
Hutton	0.4 c	16 a	16 a
Jupiter	3.4 bd	407 a	194 a

[x] Recovered at harvest

[y] Root-knot index was rated on a scale of 0-5: 0=Zero; 5=over 100 galls.

[z] Within each column, means followed by the same letter do not differ significantly at the 5% level as determined by Duncan's new multiple-range test.

Table 3. The effect of four nematicides on population of nematodes in the soil and their effect on Williams soybean yield.

Nematicides	Dosage Kg/ha	Nematode population control (%) 1/		Yield plot	
		Soil	Root	Kg/ha	Increase (%)
Aldicarb 10G	16.8	-40	88*	2670.8	7
Aldicarb 10G	33.6	5	82*	2663.7	7
Ethoprop 10G	16.8	16	52*	2166.6	-12
Ethoprop 10G	33.6	22	52*	2206.0	-11
Fensulfothion 15G	7.2	36	82*	2536.1	2
Fensulfothion 15G	14.6	65	70*	2866.0	15
Phenamiphos 15G	7.2	8	76*	2137.1	-14
Pehnamiphos 15G	14.6	39	88*	2368.7	-4
Check	---	---	---	2486.3	---

*=Significantly different at the 5% level, according to t-test.

1/Population counts were taken for both soil and 2 g of roots for each replicate before planting and 45 days after nematicide applications.

LITERATURE CITED

1. Dunn, R. A. 1978. Nematode pests of soybeans and their control. Nematol. Fact sheet No. 2, IFAS. 3 p.

2. Hartwig, E. E. and J. Epps. 1978. Bedford, a new soybean resistant to cyst nematode. Mississippi Agric. and Forestry Exp. Sta. Inf. sheet 1280. 2 p.

b. Plant Pathology (Dr. Paul Hepperly)

Production of seeds which produce vigorous even stands is essential to the maintenance and expansion of soybean production. Increased production of soybean in tropical areas could lead to better nutrition and higher living standards especially in underdeveloped countries. High temperatures and humidity common to tropical environments favors the development of soybean diseases which lower yield and seed quality. To increase the production of soybean in the tropics, current inability to consistently produce high quality seed must be remedied.

A significant portion of INTSOY Puerto Rico research is directed toward identifying and analyzing soybean diseases important in the tropics. Pathology personnel interact with personnel in agronomy, breeding, weed science, and other fields to better understand how pathological problems are related to production practices.

1. Interaction with weed science (cooperative research with Dr. G. Riveros)

Reports from Brazil and the International Institute of Tropical Agriculture (IITA) in Nigeria have associated poor weed control with the production of poor quality soybean seed. Weeds can hamper soybean production in two major ways. They compete during early growth stages of soybean reducing soybean yield and develop late in the season to increase harvest losses and difficulties. Weeds with different life cycles and growth habits have different effects on soybeans. A weed such as wild poinsettia (*Euphorbia heterophylla*) competes strongly with soybean early and then dies out before soybean harvest. Morning glory (*Ipomoea tiliacea*) besides competing with soybean early also develops extensively later and often complicates harvesting. Since seed quality could involve the climatic influence of a weed canopy during and after seed development, experimentation in the nature of different weed canopies and their effect on seed quality is important. It is unlikely that the effect of weeds on seed quality can be explained by simple comparisons of weeded and nonweeded areas. We have initiated experiments to answer: How does the competitive influence of weeds affect seed quality?; How does the presence of weed canopies at the end of the season affect seed quality?; What are the various effects of differing weed communities in determining canopy and seed quality?; What are the organisms on soybean seed which develop under the influence of various weed communities?; and, What is the potential of communities of weeds to serve as inoculum sources for organisms which on soybean act directly in lowering seed quality?

A weed competition experiment was conducted at Isabela, Puerto Rico during the rainy season. 'Williams' soybeans were planted in 30, 45, and 60 cm row spacings. Plots were either i) not weeded (full season competition), ii) weeded after allowing 5 weeks of early competition, iii) weeded

after allowing 4 weeks of early weed competition, iv) weeded after allowing 3 weeks of early weed competition, and v) weeded after allowing 2 weeks of early weed competition. Weed weights, both fresh and dry, were determined at 2 and 4 weeks. Plots were rated for weed coverage at harvest. Fifty seed from each plot were assayed by surface disinfecting them, plating them on sterile potato dextrose agar and incubating them 7 days at 25°C. Germination and mycoflora were used as quality measures.

Germination was significantly higher (48.0 and 41.2, respectively) for the 30 cm and 45 cm row spacing than for 60 cm (Table 4). There was no difference between the early competition treatments (germination of 39.6 to 46.2) but full season competition significantly reduced germination (28.9). A significant block effect was found. Germination was higher in block I (48.0) than in blocks II and III, (34.1 and 35.7).

The 60 cm row spacing, which favored weeds, reduced soybean germination. Early competition levels which had a much reduced weed canopy at harvest showed no difference in soybean germination but were higher in germination than full season competition in which an extensive weed canopy at harvest developed. The significant block effect was due to lower germination in blocks II and III compared to I. The blocks of low germination corresponded to areas showing late season morning glory coverage.

Overall seed quality is dependent partly on the presence of a weed canopy during and after seed development. Morning glory canopies appear to be particularly effective in predisposing soybean plants to seed decay. Row spacings, which suppress weeds throughout the season, result in higher seed quality.

Total number of fungal colonies (total fungi), *Cercospora kikuchii*, *Phomopsis sojae*, *Fusarium semitectum*, *Colletotrichum dematium* and other fungi (the most common being *Rhizoctonia solani* and *Botrydiploidia theobromae*) were influenced by row spacing weed competition, and field position (block effect) (Table 5). Total fungi was not different between any row spacing or competition treatment. More total fungi were found in blocks II and III, (114.9 and 111.7%, respectively) than in block I (101.6%). Germination differences were not fully explained by differences in total fungi but could be explained by compositional differences in seed mycoflora. Different organisms had differing effects on seed. *Cercospora kikuchii* infected seed almost always germinated while seed infected with other fungi usually did not. *Cercospora kikuchii* was found in 37.5% of seeds from rows of 30 cm and in 23.3% of seeds from 60 cm rows. There was no differences between competition levels or blocks in their incidence of *C. kikuchii*. The final weed canopy and development of *Ipomoea* does not appear to influence the *C. kikuchii* incidence. Higher germination at 30 cm row spacing appears partly due to higher incidence of *C. kikuchii*.

The incidence of *P. sojae*, *F. semitectum*, *C. dematium* and other fungi all except the last one were affected by row spacing. None of these were their highest in recovery at 30 cm. *C. dematium* and *F. semitectum* were highest at 60 cm and *P. sojae* at 45 cm. Full season competition resulted in higher *C. dematium* and other fungi than the early competition treatments which were not different from each other.

The significant germination difference between full season competition and early competition levels was due in part to increased development of *C. dematium* (anthracnose) and other fungi (mostly *Rhizoctonia solani* and *Botryodiploidia theobromae*). These fungi are highly pathogenic if high humidity is present. Plots covered with morning glory and other weeds apparently stimulates their development by providing a more favorable environment.

Studies to determine the effects of different weed canopies on soybean maturity, infection rates and on the pod and seed environment have begun in Lajas and Isabela. In Lajas, where johnsongrass (*Sorghum halapense*) is a dominant species, areas were selected as i) clean of Johnsongrass and other weeds; ii) infested with johnsongrass; and iii) infested with morning glory. Four replications of each area were used. One soybean plant was sampled per replicate during mid-morning and individually sealed in plastic bags. Pods were handpicked and stem moisture was determined by the weight difference before and after oven drying at 60°C for 48 hours. Seed was bulked for each treatment. Three-replication of 50 seed each were examined and rated for damaged seed and then germinated on cellulose pads. Also, sixty seed each were plated on potato dextrose agar after surface disinfection. Germination and fungi were recorded after 3 days incubation.

At Isabela, adjacent areas (9 m^2 each) of 'Jupiter' soybeans which were Ipomoea infested or noninfested were selected at two field locations. Four plants were sampled from each area. Harvested seed was visual examined for brown discoloration (anthracnose) or oospore encrustration (downy mildew). Three replications of 100 seed from each Ipomoea infested and noninfested areas were placed on moistured cellulose pads at 25°C for 7 days.

The stem moisture of mature 'Improved Pelican' soybeans at Lajas was increased in areas with morning glory coverage (Table 6). Morning glory and johnsongrass coverage reduced germination and increased seed damage. In Isabela, morning glory coverage apparently did not influence downy mildew of *F. sojae* development on seed (Table 7). Anthracnose (*C. dematium*) and purple stain (*C. kikuchii*) were higher and germination was lower in Ipomoea infested compared to noninfested areas of 'Jupiter' soybeans.

Table 4: Effects of row spacing, block position, and competition treatments on the germination of 'Williams' soybean in Isabela.

Row-Spacing[1/]	Germination
30	48.0
45	41.2
60	28.7

$LSD._{.05} = 9.3$
$_{.01} = 16.6$

Competition[1/]	Germination
Full season	28.9
5 weeks	39.6
4 weeks	42.0
3 weeks	46.2
2 weeks	40.0

$LSD._{.05} = 12.0$
$_{.01} = 21.5$

Block[1/]	
I	48.0
II	34.1
III	35.7

$LSD._{.05} = 9.3$
$_{.01} = 16.6$

[1/] Row spacing and block means based on 15 replications of 50 seed each. Blocks II & III were infested with late season morning glory (*Ipomoea tiliacea*).

[2/] Competition means based on 9 replications of 50 seed each.

Table 5. 'Williams' soybean mycoflora as effected by row spacing, competition level, and block position.

Row spacing[1/]	Total Fungi	*C. kikuchii*	*P. sojae*	*F. semitectum*	*C. dematium*	Other[3/]
30	113.7	37.5	28.5	23.7	10.4	10.7
45	109.0	30.4	39.7	24.3	4.1	11.5
60	117.5	23.3	27.3	39.5	13.0	12.7
LSD.05	NS	8.9	10.6	8.3	5.2	NS
.01	NS	15.9	19.0	14.9	9.3	NS
Competition[2/]						
Full	113.4	27.1	22.7	25.1	15.5	24.2
5 week	109.1	29.6	32.9	25.6	7.6	10.2
4 week	113.9	33.1	32.9	34.4	6.3	6.8
3 week	117.3	32.0	35.3	33.3	7.1	7.8
2 week	113.2	30.2	35.5	27.3	9.3	9.1
LSD.05	NS	NS	NS	NS	6.7	6.4
.01	NS	NS	NS	NS	12.0	11.5
Block						
I	101.6	26.9	36.1	29.1	4.0	10.3
II	114.9	33.3	23.6	26.1	11.1	14.4
III	117.7	30.9	35.9	32.2	12.5	10.1
LSD.05	9.5	NS	10.6	NS	5.2	NS
.01	17.0	NS	19.0	NS	9.3	NS

[1/] Means based on 15 replications of 50 seed each.

[2/] Means based on 9 replications of 50 seed each.

[3/] Other = Other fungi mostly *Botryodiploidia theobromae* and *Rhizoctonia solani*.

Table 6. Stem moistures and soybean seed quality of 'Improved Pelican' seed from weedless, johnsongrass (*Sorghum halapense*) or morning glory (*Ipomoea tiliacea*) infested plots. Samples were taken at mid-morning following a moderate dew at harvest maturity in Lajas, Puerto Rico.

Infestation	Stem[1/]	Seed Damage[2/]	Cellulose[2/] Pad Germination	Potato Dextrose Agar	
				Germ.[3/]	Fungi[3/]
Weedless	15.3 A[4/]	3.9 A	89.7 A	61.7	3.3
Johnsongrass	17.7 A	16.5 B	79.7 B	43.3	5.0
Morning glory	22.0 B	25.5 C	72.0 B	43.3	8.3

1/ Based on 4 replications of one plant each.
2/ Based on 3 replications of 50 seed each.
3/ Based on germination of 60 surface sterilized seed on potato dextrose agar for each treatment.
4/ Means in the same column followed by different upper case letters are statistically different at P=.01 using FLSD.

Table 7. Quality of 'Jupiter' soybean (*Glycine max*) seed from areas infested with morning glory (*Ipomoea tiliacea*) or from noninfested area at Isabela, Puerto Rico 1979.

	Seed Assessments					
	Visual Assay (%)[2/]		Cellulose Pad Assay (%)[3/]			
	Brown Discoloration	Oospore Encrustation	Germination	*Colletotrichum dematium*	*Phomopsis sojae*	*Cercospora kikuchii*
Ipomoea[1/] Infested	4.3	8.6	74.8	10.1	6.0	21.0
Noninfested[1/]	0.6	6.6	87.5	2.9	6.0	8.7
	**	NS[5/]	**	**	NS	**

[1/]Adjacent areas which were *Ipomoea* infested and noninfested (9 m^2 each) were sampled (4 plant each) at two locations.

[2/]Seed with brown discoloration (anthracnose symptoms) and oospore encurstations (downy mildew) were counted in 3 replicates of 100 seed from seed of each Ipomoea infested or noninfested areas.

[3/]Three replications of 100 seed from each Ipomoea infested and noninfested areas were germinated on moistened cellulose pads for 7 days at 25°C.

[4/]Double asterisks indicates highly significant difference between Ipomoea infested and noninfested areas (P = 0.01) based on t-test.

[5/]NS - no statistical difference based on t-test (P=0.05).

2. Tropical Diseases on Soybean

a. Soybean anthracnose has not been reported in Puerto Rico. During the rainy season of 1979 serious damage from this disease was widespread in Isabela. Following prolonged rainy periods in May 1979 the disease developed on soybeans maturing in June. Symptoms included leaf rolling, necrosis of laminar veins, petiole cankering and premature dropping of leaflets. Elongated rectangular lesions, which were at first red then black, developed. In severe infected plants stem apices became necrotic, plants appeared stunted and pods matured first at the upper nodes. The severe symptoms of anthracnose were found in up to 50% of the plants of the variety 'Cobb'. Reduction in plant height, pod and seed numbers were found associated with diseased plants of 'Jupiter' and 'Cobb' (Table 8). Low percentages (<20%) of soybean seed showed *Colletotrichum dematium* as the causal fungus. This fungus was identified after seed was surface sterilized and plated on potato dextrose agar. When seeds were assayed on cellulose pads up to 70% of seed showed infection. Paired analysis of the two methods revealed more *C. dematium* when assayed on pads than on agar plates (Table 9). An inverse relationship (r=-0.71**) was found between the percentage of seeds with anthracnose signs and the percentage of seed with pod and stem blight signs when 12 seedlots were analyzed on pads (Fig. 1). Agar plate assay which did not favor detection of *C. dematium* favored detection of *Phomopsis sojae*, the pod and stem blight fungus (Tables 10, 11 and 12).

The results of these studies indicates that anthracnose was a damaging disease under the tropical humid conditions of Isabela, Puerto Rico. The inability of previous work to identify it as a major component of seedborne mycoflora was probably due to the use of assay conditions which didn't favor the expression of *C. dematium*. No high degree of resistance to this disease has been identified and work in cooperation with the soybean breeder will attempt to develop resistance to this disease in tropically adapted soybean genotypes.

b. Web blight of soybean caused by *Rhizoctonia solani* has never been reported in Puerto Rico and has only been reported in Louisiana, Mexico, Philippines and Taiwan. The disease is found only in subtropical and tropical areas where prolonged high humidity is prevalent. The disease first appeared on 'Davis' soybeans in Corozal, Puerto Rico. Infected foliage becomes chlorotic then necrotic turning from yellow to grey-brown. Greyish mycelial threads were often visible on dead leaves. Numerous dark brown sclerotia which are irregularly rectangular (1/4 to 1/2 mm in legth) were formed on petioles. Dead leaves cemented together with mycelium

Table 8. Comparisons of 'Cobb' and 'Jupiter' soybean plants that were prematurely killed with anthracnose or not showing symptom development.

Cultivar	Symptom Expression	Plant Height[a/] (cm)	Pod[a/] (no.)	Seed[a/] (no.)
Cobb	Prematurely killed with anthracnose	27.5	43.4	85.4
	Without Anthracnose signs or symptoms	34.9	81.4	156.4
		NS[b/]	**[b/]	**[b/]
Jupiter	Prematurely killed with anthracnose	28.3	49.3	96.3
	Without Anthracnose signs or symptoms	37.5	64.2	160.3
		*[b/]	NS[b/]	**[b/]

a/ Based on 5 plants for each symptom expression for each cultivar.

b/ Unpaired comparison of two sample means: NS - no significance; * - significance at P = 0.05; and ** - significance at P = 0.01 based on the t-test.

Table 9. A comparison of the potato dextrose agar assay with the cellulose pad assay for determination of seed infection by *Colletotrichum dematium* (Pers. ex Fr.) and *Phomopsis sojae* (Leh.) in soybean (*Glycine max* (L.) Merr.).

Cultivar	Planting Date[1]	Percentage of Seed with *Colletotrichum dematium* PDA[2]	*Colletotrichum dematium* Cellulose[3]	*Phomopsis sojae* PDA[2]	*Phomopsis sojae* Cellulose[3]
Hardee Late Selection	3-1	18	64	86	34
Improved Pelican	3-1	12	10	84	65
IAC - 2	3-15	8	21	32	21
Orba	3-15	2	2	60	65
UFV-1	3-15	6	49	20	9
Improved Pelican	3-15	4	15	30	40
Bragg	4-2	6	16	44	15
Cobb	4-2	4	61	4	4
Cutler '71	4-2	4	1	88	77
Forrest	4-2	8	15	86	77
Williams	4-2	2	0	72	79
	$\bar{X}$	6.7	23.1	55.1	44.0

$t = \frac{\bar{D}}{S_{\bar{D}}} = 2.49$ $\quad$ $t = \frac{\bar{D}}{S_{\bar{D}}} = 2.07$

$t_{.10,10} = 1.812$

$t_{.05,10} = 2.228$

$t_{.01,10} = 3.169$

1/ All cultivars were harvested July 13th at green full bean to harvest maturity.

2/ Means based on 50 seed each. Seeds were surface disinfected with .5% NaOCl for 4 minutes and plated on sterile potato dextrose agar, and incubated 7 days at 25°C.

3/ Each mean based on 100-300 seed. Seed were placed directly on cellulose pads without surface disinfection and incubated 7 days at 25°C. Fungi were identified by signs under the stereoscope (70X) and confirmed under the compound microscore (400X).

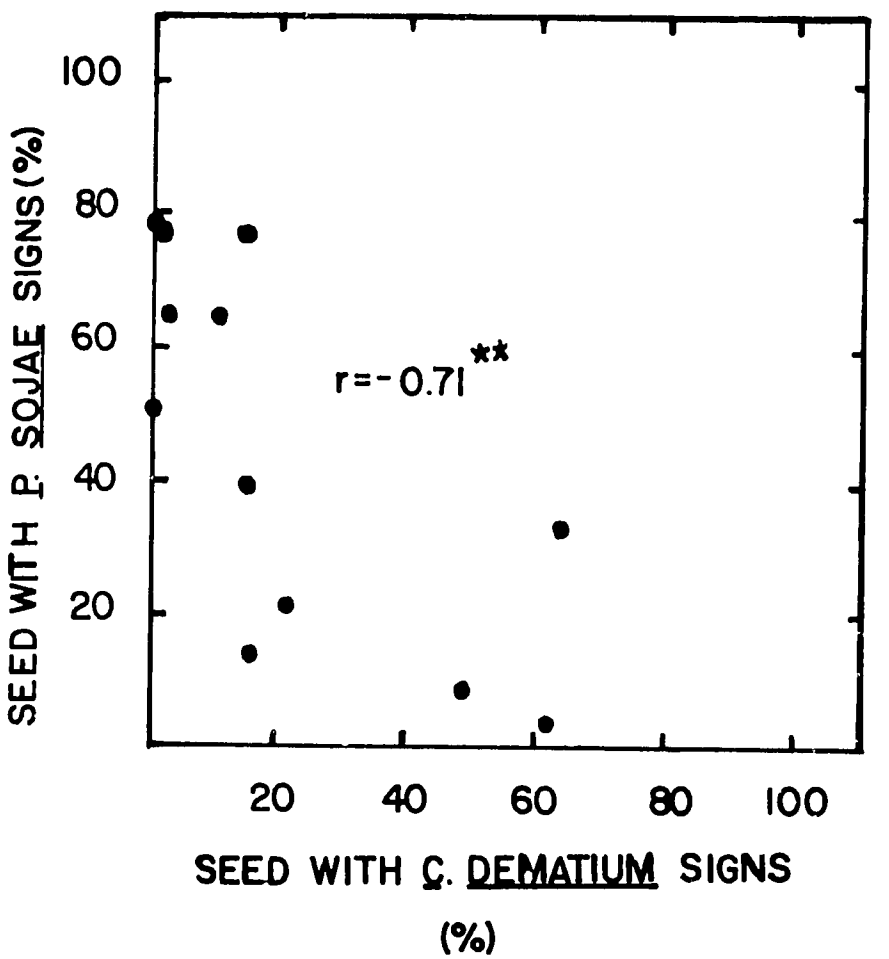

Fig. 1. The relationship of seed with *P. sojae* and seed with *C. dematium* signs in soybean seedlots germinated for 10 days on cellulose days at 95 RH and 25°C.

Table 10. The effect of surface treatment (10% Clorox at 4 minutes) and potato dextrose incubation (1 week at 25°C) on the seedborne incidence of *Colletotrichum dematium* in soybean seeds separated for presence of *Colletotrichum dematium* when incubated on cellulose pads (1 week, 25°C and 95% RH).

Cultivar	Seedborne Incidence *Colletotrichum dematium* % Cellulose[1/]	Potato dextrose agar[1/]	Difference
Improved Pelican	100	22	78
IAC-2	100	9	91
Cobb	100	11	89
$\bar{X}$	100	14	86

$$t = \frac{\bar{d}}{s_{\bar{d}}} = 21.2^{**}$$

$$t_{.01.2} = 9.925$$

[1/] Based on 50 - soybean seed from each cultivar showing *Colletotrichum dematium* after incubation on cellulose pads.

Table 11. The effect of surface treatment (10% Clorox at 4 minutes) and potato dextrose agar incubation (1 week at 25°C) on the seedborne incidence of *Phomopsis sojae* in soybean seeds separated for presence of *Phomopsis sojae* when seeds were incubated on cellulose pads (1 week, 25°C and 95% RH).

	Percentage Seedborne Incidence of *Phomopsis sojae*		
Cultivar	Cellulose[1/]	Potato dextrose agar[1/]	Difference
Improved Pelican	100	62	38
IAC-2	100	67	33
Cobb	100	73	27
$\bar{X}$	100	67	33

$$t = \frac{\bar{d}}{s_{\bar{d}}} = 10.3^{**}$$
$$t_{.01,2} = 9.925$$

[1/] Based on 50 soybean seed from each cultivar separated for their presence of *Phomopsis sojae* after cellulose pad incubation.

Table 12. A paired comparison of the reductions in seedborne incidence occurring when using the potato dextrose agar plating method for *Colletotrichum dematium* and *Phomopsis sojae*.

Cultivar	Percentage Reduction of Incidence Using Potato dextrose agar method		Difference
	Colletotrichum dematium[1/]	*Phomopsis sojae*[2/]	
Improved Pelican	78	38	40
IAC-2	91	33	57
Cobb	89	27	62
$\bar{X}$	86	33	43

$$t = \frac{\bar{d}}{s_{\bar{d}}} = 7.6^*$$

$$t_{.05,2} = 6.965$$

$$t_{.01,2} = 9.925$$

1/Fifty seed from each cultivar was separated for having *Colletotrichum dematium* acervuli. Reduction is: 100 - recovery on potato dextrose agar.

2/Fifty seed from each cultivar was separated for having *Phomopsis sojae* pycnidia. Reduction is: 100 - recovery on potato dextrose agar.

become plastered to central nodes of infected plants. Pods which are covered with infected leaves developed sunken tan lesions of several mms in length. Infected seeds developed in pods with lesions. Infected seeds showed tan discoloration of the seed coat and seed coat cracking. Infected seed may germinate in the pod in the field. Seed that germinated were rotted from the radicle tip. In plots not receiving weekly applications of benomyl (methyl-1-(butylcarbamoyl-2-benzimidazole-carbamate) Benlate 50 WP, E. I. DuPont de Nemours, Wilmington, Delaware), symptoms developed near full green bean stage, while in plots receiving weekly benomyl sprays, symptoms appearance was delayed by 14 days. Disease progress was monitored through harvest by counting disease foci and estimating the area of the largest focus. The disease increased exponentially with plant maturity (Fig. 2A). Disease measurements were closely correlated. Seed infection of *R. solani*, were detected from 5% or less of seed from infected plants but not in plants without web blight symptoms. Middle nodes, where dead infected leaves gathered were the only ones bearing infected seed (Fig. 2B). Compared to seed from symptomless plants, seeds from plants with web blight had reduced numbers of other fungi and greater germination (Table 13). Web blight apparently inhibited development of the more common seedborne fungi on soybean.

Other workers have found that *R. solani* contains many isolates which may not interchange genetic material and appear to be biological species. Isolates associated with aerial blights belong to one of such category (anastomosis group I, AGI). Seed infection of *R. solani* which is a cause of basal root and stem rot is associated with plant fruit contact with soil (soil rot of pods). This is not the case for *R. solani* in aerial blight as was found in Corozal. The seedborne nature of these isolates may be significant for its spread. Web blight appears to have the potential of a limiting disease on tropical soybeans. Additional work on the etiology, epidemiology and ecology of this disease is needed.

Fusarium diseases - A number of *Fusarium* species have been found associated with diseased plants at Isabela, Puerto Rico in 1979. Previous seed pathology reports of this project have reported that *Fusarium semitectum* is commonly seedborne in soybean (*Glycine max*), pigeon pea (*Cajanus cajan*), bean (*Phaseolus vulgaris*) and cowpea (*Vigna unguiculata*) in Puerto Rico. The role of this fungus in determining the quality of soybean seed is uncertain. Although strong associations exist between the incidence of this fungus and lowered germination, artificial inoculations of clean seeds with *F. semitectum* do not reduce emergence in soil or sand.

During the report period, it was observed that *F. semitectum* was associated with pod abortion in some soybean varieties and with pod borer (*Heliotus virescens*) damage in all

Fig. 2. A. The infection of Davis soybean seed in relation to pod position.
B. Development of web blight disease foci in nonsprayed and benomyl sprayed fields of Davis soybean.

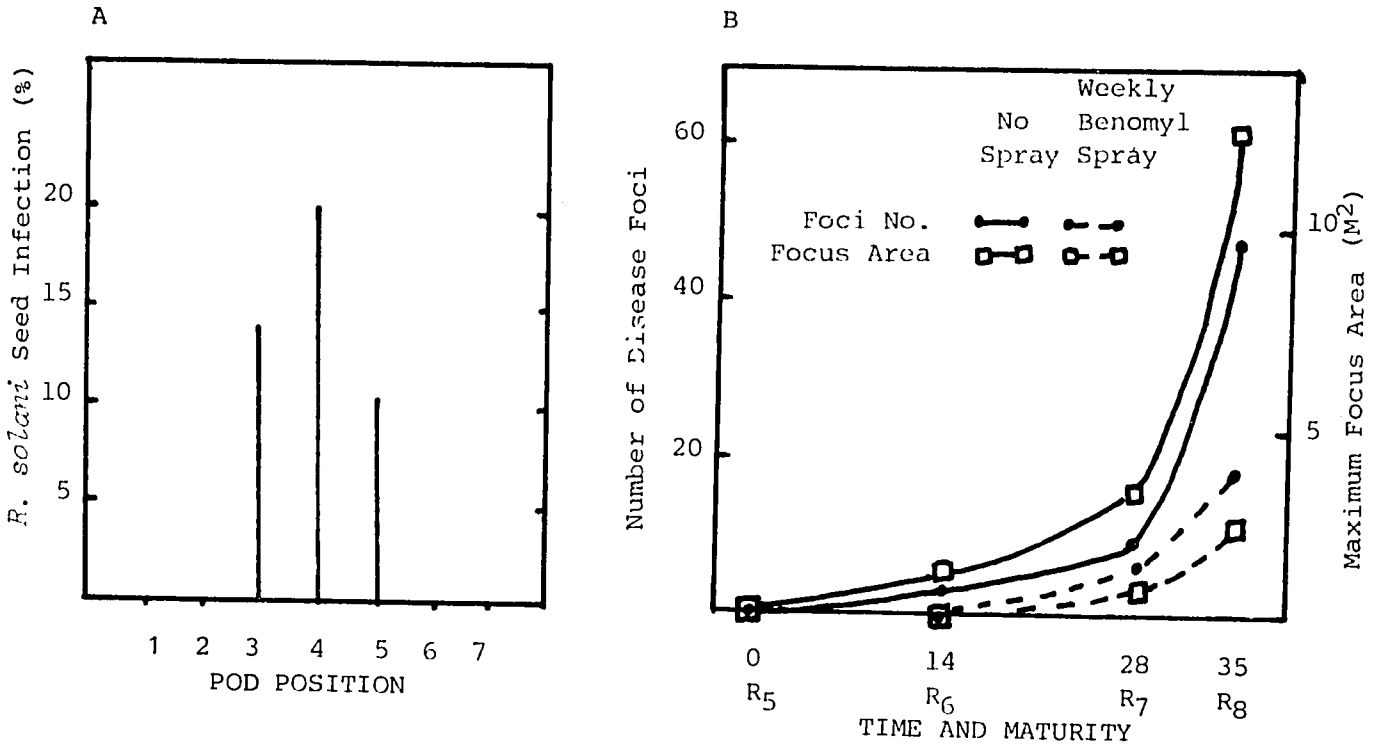

Table 13. Germination and mycoflora of Davis soybean seed from plants with and without web blight at Corozal, Puerto Rico.

Type of Plants[3]	Cellulose pads assay[1]		Potato dextrose agar assay[2]						
	Germ. (%)	*R. solani* (%)	Germ. (%)	Total Fungi (%)	*R. solani*[4] (%)	*P. sojae*[4] (%)	*C. dematium*[4] (%)	*B. theobromae*[4] (%)	*C. lunata*[4] (%)
Web blighted	56.5	4.0	53.2	30.0	5.0	9.5	0.0	0.0	0.0
Symptomless	37.0	0.0	32.6	68.5	0.0	17.4	3.2	3.2	2.6
	*[5]	*	*	*	*	*	*	*	*

[1] Seed germinated on moistened cellulose pads for 10 days at 25°C.

[2] Seeds were surface disinfected (10% clorox for 4 mintues), plated on sterile potato dextrose agar, and incubated for 10 days at 25°C.

[3] Based on paired samplings. Three symptomless and three adjacent diseased plants were selected in five areas throughout a .5 ha experimental field.

[4] Data transformed by a square root transformation.

[5] Statistically significant at P=0.05 using a paired t-test.

varieties. To investigate the indirect influence of *H. virescens* on seed quality and seedborne mycoflora, pods of Forrest soybean were collected. Pods were selected in two groups: 1) those invaded by *H. virescens* as evidenced by the presence of a borer hole in the pod (damaged pod) and 2) those not invaded by the insect. Equal numbers of both pod types were harvested at each plant node sampled. Seeds from 4 groups of 25 pods which were not invaded by *H. virescens* and uneaten seed from 4 groups of 50 pods with pod borer holes were surface disinfected, plated on potato dextrose agar, and incubated for 7 days at 25°C. Germination of seed from pod borer invaded pods was 12.7% compared to 42.0% for seed from pods which were not invaded. *F. semitectum* recovery from seed of invaded pods was 27.0% over four times that of seed from intact pods (5.9%). There was no significant difference for total fungi recovered but seed from pods which were not invaded had increased *P. sojae*. Assay values and their significance are shown in Table 14.

One hundred aborted pods of various soybean varieties were collected from Isabela in June 1979. The following fungi were detected on these pods: *Fusarium semitectum* (85%), *Colletotrichum dematium* (7%), *Phomopsis sojae* (3%), *Botryodiploidia theobromae* (3%), and *Alternaria tenuissima* (2%).

Aborted pods are commonly colonized by *F. semitectum*. The role of these as an inoculum source should be further examined. *F. semitectum* appears to be an important cause of soybean decay in pod borer damaged pods. *F. semitectum's* limited pathogenicity in vitro may be due to an increased resistance in mature seed compared to seed developing in the pod in the field. For continuing studies, it should be determined if *H. virescens* can vector *F. semitectum*.

Fusarium oxysporum, *Phialophora gregata* and *Verticillium* spp. are reported as causes of soybean wilt. For the first time a wilt disease of soybean was observed in Isabela, Puerto Rico in 1979. Scattered groups of plants (1-20) were wilted a full green of yellow bean stage. Vascular discoloration extended up to 6 nodes in plants with symptoms. Isolations from diseased plants showed *Fusarium solani* as the most commonly associated fungus with wilting. In wilted plants *F. solani* was recovered from 10% of infected seeds but was not recovered in seeds from neighboring plants not showing wilt. Sixty soybean seeds of the variety 'Williams' were either inoculated with *F. solani* or nontreated and planted in sterile soil in sterile glass containers supplied with nutrient solution. Sixty percent of the control seed emerged

Table 14. The effect of pod entry by pod borer (*Heliotus verescens*) on germination of intact Forrest soybean seed and their mycoflora.

Seeds from	Germ.	*F. semitectum*	*P. sojae*	Total Fungi
Uneaten seed[1/] in pod borer invaded pods	12.7[1/]	27.0[1/]	16.0[1/]	58.0[1/]
Seed from Non-invaded pods[2/]	42.0[2/] ** [3/]	5.8[2/] **	54.1[2/] **	68.0[2/] NS[4/]

[1/]Based on intact seed from 4-groups of 50 pod borer invaded pods.
[2/]Based on seed from 4-groups of 25 pods which were not invaded by pod borer.
[3/]Statiscally significant at P=0.01 level based on unpaired t-test.
[4/]No statistically difference at P=0.05 based on unpaired t-test.

Table 16. International Bean Bacterial Blight Nursery

Mita No.	Other Designation	Origin
10551	P787	Perú 0257
10552	P287	PI 307.466 Tupi Claro
10553	P46	PI 151.380
10554	F425	Corriente 082
10555	P507	California Small White
10556	P539	Venezuela 2
10557	P542	Venezuela 58
10558	P761	Guatemala 417
10559	P778	Cundinamarca 115
10560	P779	Cundinamarca 116
10561	P786	Br. 2, 349 (Mulatinho)
10562	P793	Chimaltenango 2
10563	P567	Tara
10564	Valley	
10565	Star	
10566	Tepary Nebraska Acc. #10	
10567	P698 Jules	
10568	Red Kidney	
10569	Emerson	
10570	P634 ICA-Duva	
15-R-55		Puerto Rico Bean Project
Mex. 309		Puerto Rico Bean Project

3. Interaction with Puerto Rico grant for Development of Control of Diseases and Insects on Bean (cooperative research with Dr. J. Mignucci).

During the last year, the INTSOY/UPR pathologist worked in cooperation with personnel of AID contract in the Improvement of Tropical Production of Beans and Cowpeas through Disease and Insect Control. A disease of major concern on dry beans is bacterial blight. To date no high level of bacterial blight resistance has been identified or developed in *Phaseolus vulgaris*.

Twenty bean (*Phaseolus vulgaris*) lines of the International Bean Bacterial Blight Nursery and two lines of the Puerto Rico project were planted in a randomized complete block design with five replications at Mayaguez (Table 16).

The susceptible cultivar Mexico 309 was sprayed with a *Xanthomonas phaseoli* (E. F. Sm.) Dows suspension after sand blasting when plants were at the four-leaf stage. These beans (planted perpendicular to the test lines) were the source of the bacteria for the test lines. A sprinkle irrigation system maintained high humidity in the plots and helped spread the bacteria. Disease development was rated at 10 days after inoculation, at full flowering and at physiological maturity. At the first rating date significant differences were found between lines for percentage of leaf area with lesions (Table 17). At later rating dates no differences were found between lines. Premature defoliation occurred on all lines. Yet, difference between the highest and lowest yielding lines was more than 100 fold (Table 18). Lines selected in Puerto Rico for multiple disease resistance had the highest yields. Germination (Table 18) of harvested seed was inversely proportional to the level of fungus infection (r=0.92**). There was no association of bacteria level with germination (r=0.0NS) and all seed carried *Xanthomonas phaseoli*. Yield was directly related to germination of seed (r=0.72**).

Table 17. Mean % leaf area covered by bacterial blight on selected *Phaseolus vulgaris* lines.

Line No.	Assessment Date		
	March 23	April 17	April 27
10551	6.0[1]	11.6	36.0
10552	4.4	13.2	34.0
10553	2.4	16.4	44.0
10554	9.8	22.6	52.0
10555	4.8	10.0	39.0
10556	*[2]	4.3	20.0
10557	3.4	18.0	48.0
10558	5.0	14.2	37.0
10559	7.8	16.6	38.0
10560	6.4	15.6	32.0
10561	8.2	12.0	42.0
10562	4.0	14.8	34.0
10563	2.0	30.0	70.0
10564	5.0	19.0	57.5
10565	0.4	7.0	46.0
10566	0.4	46.0	Def.[3]
10567	0.2	13.4	42.5
10568	5.2	33.0	60.0
10569	0.0	13.0	27.5
10570	13.0	20.0	48.0
15-R-55	3.0	14.0	34.5
Mex. 309	2.7	11.0	41.5

[1] Mean of 5 replications
[2] * no emergence
[3] Def. = Complete defoliation

Table 18. Seed assay of selected *Phaseolus vulgaris* lines for germination and recovery of bacteria and fungi - Bacterial Blight Trial - 1979.

	Recovery (%)		
Line No.	Total Fungi[1]	*Xanthomonas phaseoli*[2]	Germination (%)[3]
10551	--[4]	--	--
10552	80	100	18
10553	68	100	12
10554	40	100	64
10555	76	100	14
10556	--	--	--
10557	74	100	36
10558	38	100	66
10559	--	--	--
10560	--	--	--
10561	78	100	14
10562	74	100	22
10563	72	100	18
10564	66	100	4
10565	74	100	2
10566	100	100	0
10567	94	100	0
10568	90	100	0
10569	--	--	--
10570	--	--	--
15-R-55	21	100	78
Mex. 309	73	100	34

[1] Assay for total fungi was done in cellulose pads in a germinator at 25°C and 90% RH. A correlation of r=-0.92** was found between total fungi and seed germination.

[2] Assay for *X. phaseoli* was done on PDA + benomyl (5 ppm) at 30°C. A nonsignificant correlation was found between bacteria recovery and seed germination.

[3] Germination was recorded on cellulose pads at 25°C, 90% RH after 6 days incubation.

4. Seedborne Microorganisms

INTSOY culture collection was initiated in 1975 to maintain microorganisms associated with soybean seed under tropical conditions. Of 35 fungi tested from this collection, less than 10 of these were important in reducing seed quality. During 1978-1979, the following fungi were identified on soybean seed *Aspergillus niger*, *Fusarium oxysporum*, *Fusarium rigidisculum*, *Fusarium solani*, *Harpographium* sp., *Mucorsp.*, *Myrothecium roridium*, *Rosellina* sp., and *Tubercularia* sp. Compilation of microorganisms associated with soybean will be a continuing effort of the project.

Table 15. Fungi and Bacteria identified on soybean seed in Puerto Rico.

Fungi	
1. *Acremonium* sp.	29. *Harpographium* sp.
2. *Alternaria alternata*	30. *Helminthosporium* sp.
3. *Alternaria tenuissima*	31. *Leptosphaerulina* sp.
4. *Arthrinium* sp.	32. *Macrophoma* sp.
5. *Aspergillus chevaliere*	33. *Macrophomina phaseolina*
6. *Aspergillus flavus*	34. *Mucor* sp.
7. *Aspergillus niger*	35. *Myrothecium roridum*
8. *Aspergillus oxyzae*	36. *Nigrospora oxyzae*
9. *Aspergillus sidowii*	37. *Nodulosporium* sp.
10. *Botryodiploidia theobromae*	38. *Papularia*
11. *Cercospora kikuchii*	39. *Penicillum notation*
12. *Chaetomium cuprinum*	40. *Penicillum* sp.
13. *Chaetomium globosum*	41. *Periconia minutissima*
14. *Chaetophoma* sp.	42. *Pestalotia* sp.
15. *Choanephora* sp.	43. *Phialophora gregatia*
16. *Cladosporium cladosporioides*	44. *Phoma herbarum*
17. *Colletotrichum dematium*	45. *Phomopsis sojae*
18. *Colletotrichum gloeosporioides*	46. *Rhizoctonia solani*
19. *Corynesporna cassiicola*	47. *Rhizopus* sp.
20. *Curvularia lunata*	48. *Rosellina* sp.
21. *Drechslera* sp:	49. *Sclerotium rolfsii*
22. *Epicoccum* sp.	50. *Syncephalastrum* sp.
23. *Eremascus* sp.	51. *Tricocladium* sp.
24. *Fusarium oxysporum*	52. *Trichoderma* sp.
25. *F. rigidiusculum*	53. *Tubercularia* sp.
26. *F. semitectum*	54. *Vermicularia* sp.
27. *F. solani*	55. *Xylaria* sp.
28. *Gliocladium* sp.	

Bacteria
1. *Bacillus subtilus*
2. *Xanthomonas phaseoli* var. *sojensis*

c. WEED SCIENCE (Dr. Guillermo Riveros)

Results from previous work conducted under the Grant have shown that a good chemical weed control treatment increased soybean yield from 60 to 80% in comparison to non-treated plots. The response to weed control is greater in years where conditions favor vigorous weed growth and in areas highly infested with weeds.

Yield increases due to weed control are not always proportional to the reduction of weed number and weight. One treatment that reduced weed number by 92% compared to the unweeded plots yielded 35% less soybean grain that other treatment that reduced weed number by 85%, the difference being the degree of control of morning glory (*Ipomoea tiliacea*). Other uncontrolled weeds that reduce drastically soybean yields are Johnsongrass (*Sorghum halepense*) and wild poinsettia (*Euphorbia heterophylla*). Only slight yield reductions have been observed when woodsorrel (*Oxalis intermedia*) is not controlled.

It also has been shown that the critical time of weed competition with soybeans occurs between the third and fifth week after emergence and that competition develops earlier when the conditions are more favorable for plant growth. These findings illustrate the importance of timing weed control operations. Limited data on mechanical cultivation showed that one cultivation given at 24 days after crop emergence, although it did not eliminate weeds completely was as effective as 2 hand weedings given at 15 and again at 30 days, to prevent yield losses.

Work completed or started within the present reporting period is as follows:

1. Effect of row spacing of 3 soybean cultivars in weed growth, Isabela.

This trial was conducted to evaluate how cultivars of different plant height, leaf size and growth period, influence the amount and kind of weeds that grow associated with them. It was also intended to determine the effect of row spacing in weed growth and to compare the effectiveness of a recommended herbicide treatment with hand weeding. Soybean cultivars Improved Pelican, Jupiter and Williams were planted on July 11, 1978, in rows 30 and 60 cm apart in plots 2.40 m wide by 6.0 m long. Seeds were inoculated with granular Nitragin at recommended rates. Superphosphate was also added at planting time at a rate of 100 Kg P_2O_5 per hectare. Weed control treatments were: i) no weeding, ii) hand weeding and iii) chemical control consisting in a preemergence application of metribuzin and alachlor (0.5 + 1.0 Kg a.i/ha.). To assess weed growth samples were taken in three 25 x 50 cm frames from the unweeded plots from the 4th to the 7th week after emergence and the number, fresh and dry weight of weeds was determined. Prevalent weeds species in the experimental area were wild poinsettia (*Euphorbia heterophylla*), woodsorrel (*Oxalis intermedia*) and morning glory (*Ipomoea tiliacea*).

The results of this trial showed that a larger number of weeds higher fresh and dry weights developed in the plots where soybeans were planted in rows 60 cm apart compared to the planting at 30 cm. It was also observed that there was more weed growth associated with cultivars Jupiter and Williams and less with Improved Pelican.

Yields of the cultivars Improved Pelican and Williams were higher when planted in rows separated 30 cm than in rows 60 cm apart. The cultivar Jupiter yielded similarly at both row distances.

Yield reduction due to weed competition was 28.9, 26.5 and 10.3% for cultivars Williams, Jupiter and Improved Pelican, respectively. Chemical control effectiveness to prevent yield losses due to weed competition was in decreasing order from Jupiter, Improved Pelican and Williams.

At present there is work underway to study the seasonal variations of weed competition with 2 soybean cultivars at 3 row spacings.

2. Evaluation of preplant incorporated (PPI) and postemergence herbicides, Lajas.

A herbicide trial was established in Lajas with the purpose of evaluating the performance of four preplant incorporated, eight postemergence over the top and six postemergence directed treatments in a field densely infested with Johnsongrass. Planting was performed on June 8th. Plots receiving PPI treatments were sprayed prior to planting and the herbicides incorporated with a rototiller. Postemergence treatments either directed or over the top were sprayed on July 2nd when soybeans had 3 unfolded trifoliate leaves.

Evaluation of the PPI treatments two weeks after their application (Tables 16 & 17) showed only very light symptoms of phytotoxicity. At this time good control was observed with the four treatments although profluralin and the combination trifluralin/metribuzin gave somewhat better control. These two treatments had over 70% control one month after the applications. Of the over the top postemergent treatments only acifluorfen at 0.75 provided good control but caused moderate symptoms of toxicity to soybeans. This treatment seems to be very promising under the conditions of Lajas.

Postemergent directed applications of glyphosate 1.0 provided excellent weed control. Very good control was observed in the plots treated with paraquat 0.25 in combination with oxyfluorfen 0.25 or acifluorfen 0.5 in postemergence directed sprays. Lower weed numbers and weights were registered at 4 weeks after emergence in the plots treated with acifluorfen 0.75, acifluorfen 0.5 plus paraquat 0.25, glyphosate 1.0, oxyfluorfen 0.25 plus paraquat 0.25 and acifluorfen 0.5. In the plots where paraquat was applied weeds recovered after 2 weeks and caused reduced yield. Chemical treatments that provided the highest yields were Bentazon 0.75 postemergence over the top followed by a directed application of glyphosate 1.0 one week later, oxyfluorfen 0.5; acifluorfen 0.75 postemergence, glyphosate 1.0 postemergence directed, and trifluralin plus metribuzion (2.0/0.5) PPI.

Table 16. Evaluation of preemergence applied herbicides. Lajas 1979.

Degree of injury, percent control and yield

	Injury		Percent Control		% Area Covered	Yield
	July 5	July 19	July 5	July 19	Oct. 30	Kg/h
1. Alachlor	1.3	0.0	53	50	59	892.6
2. Metolachlor	0.7	0.0	53	47	42	1093.3
3. Oryzalin	0.7	0.7	43	50	67	918.1
4. Metribuzin	2.7	1.3	80	77	60	895.8
5. Linuron	0.7	0.0	57	53	68	879.2
6. Oxyfluorfen	0.7	0.0	98	93	9	1406.0
7. Alachlor / Metribuzin	1.3	0.7	77	72	48	968.0
8. Oryzalin / Metribuzin	1.3	0.7	83	83	23	1159.7
9. Metolachlor / Metribuzin	1.3	1.3	52	58	62	634.7
10. Alachlor / Oxyfluorfen	0.3	0.0	93	93	25	1331.0
11. Handweeded	0.0	0.0	100	100	19	1137.5
12. Unweeded	0.0	0.0	00	00	72	747.6

Date of planting and application June 19, 1979.
Handweeded control cleaned June 28 and July 11.
Harvesting October 30, 1979.

Table 17: Evaluation of Preplant Incorporated (PPI) and postemergence herbicides Lajas 1979.

Weed number and weed weights in .375 m^2 at 4 weeks after crop emergence

				Weed Number					Weed Weight				
				A	B	C	D	Total	A	B	C	D	Total
1.	Trifluralin	2.0	PPI	17.0	2.7	14.3	8.0	42.0	130.3	4.5	31.4	9.6	175.8
2.	Profluralin	2.0	PPI	3.7	0.7	5.0	8.3	17.7	46.5	0.2	6.9	10.6	64.2
3.	Penoxalin	2.0	PPI	9.3	0.0	11.0	5.3	25.6	47.8	0.0	14.9	3.7	66.4
4.	Trifluralin / Metribuzin	2.0 / 0.5	PPI	10.3	1.3	13.7	3.0	28.3	107.5	3.2	21.0	6.7	138.4
5.	Dalapon	10.0	POST D	14.3	3.0	2.7	4.7	24.7	96.3	2.8	2.0	4.6	105.7
6.	Bentazon / Glyphosate	0.75 / 1.0	POST T / POST D	46.7	17.3	0.7	9.7	74.4	357.6	11.6	.7	13.5	383.4
7.	Bentazon	1.5	POST T	42.3	19.3	2.7	7.3	71.6	231.5	27.2	2.3	5.2	266.2
8.	Oxyfluorfen	0.25	POST T	41.0	25.7	7.0	0.7	74.4	252.2	31.5	7.8	0.6	292.1
9.	Oxyfluorfen	0.5	POST T	38.3	25.7	3.3	2.3	69.6	87.6	22.4	3.1	1.4	114.5
10.	Acifluorfen	0.5	POST T	23.7	22.3	7.3	3.3	56.6	32.2	15.7	8.2	3.3	59.4
11.	Acifluorfen	0.75	POST T	9.3	34.7	3.0	3.3	50.3	12.5	24.4	2.0	0.2	39.1
12.	Methazole	2.0	POST D	14.3	2.0	9.7	0.7	26.7	58.1	1.5	16.3	0.6	76.5
13.	Methazole	3.0	POST D	15.7	0.0	2.7	0.3	18.7	56.3	0.0	2.5	1.1	59.9
14.	HOE 23408	0.75	POST T	68.7	9.0	3.7	19.3	100.7	328.9	9.6	5.9	12.9	357.3
15.	Glyphosate	1.0	POST	19.3	0.3	0.7	2.7	23.0	18.2	1.0	0.4	0.9	20.5
16.	Oxyfluorfen / Paraquat	0.25 / 0.25	POST D	5.0	4.3	2.3	1.3	12.9	22.4	0.8	2.2	2.4	27.8
17.	Acifluorfen / Paraquat	0.5 / 0.25	POST D	4.7	4.3	4.7	0.0	13.7	14.7	2.3	4.7	0.0	21.1
18.	HOE 23408 / Linuron	0.75 / 0.75	POST T	6.0	1.0	6.7	1.0	14.7	39.5	1.4	10.5	0.8	52.2
19.	Handweeded			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	---
20.	Unweeded			31.3	26.3	5.7	11.3	74.6	268.3	28.9	9.7	16.0	322.9

A - Johnsongrass (*Sorghum halepense*)
B - Jungle Rice (*Echinochloa colonum*)
C - Nutgrass (*Cyperus rotundus*)
D - Other weeds: spreading dayflower (*Commelina diffusa*); wild poinsettia (*Euphorbia heterophylla*); morning glory (*Ipomoea tiliacea*).
- Date of sampling July 12, 1979

3. Evaluation of preemergence applied herbicides, Lajas.

Six products were tested alone and in combinations. Scores of degree of phytotoxicity and control are presented in Table 3. According to this data metribuzin at 0.5 gave the higher score two weeks after planting but toxocity was light. Very light symptoms were still evident at four weeks in all the plots treated with metribuzin and also in those receiving oryzalin 1.0.

Excellent control (more than 90%) was observed at two weeks in the plots treated with oxyfluorfen 1.0 and with oxyfluorfen 0.5 plus alachlor 2.0. Between 77 to 83% control was obtained at that date with the treatments oryzalin 1.0 plus metribuzin 0.5; metribuzin 0.5; and alachlor 2.0 plus metribuzin 0.5. The same treatments showed over 70% control 4 weeks after planting. Table 4 shows that lowest Johnsongrass number and weight was registered at 4 weeks in the plots treated with oxyfluorfen 1.0 and with oxyfluorfen 0.5 plus alachlor 2.0. These plots and those treated with oryzalin 1.0 and metribuzin 0.5 had the lowest area covered with weeds at harvesting and also provided the highest yields (Tables 18 & 19).

4. Herbicide evaluation, Isabela, 1979.

Selected treatments from previous trials were evaluated together with some compounds of more recent development. Treatments are shown in the tables of results (Tables 20 and 21).

This trial was planted June 25th. It consisted of twenty treatments replicated three times. Plots size was 3 m wide (5 rows 60 cm apart) by 10 m long. Preplant incorporated treatments were applied the same day of planting and preemergence treatments the following day. Postemergence compounds were applied three weeks after planting when soybeans were at the V4 growth stage.

Soybean seeds of cultivar Improved Pelican were sown with a hand planter. Granular Nitragin was mixed with the seed in the box of the planter. Triple superphosphate at a rate of 100 Kg/ha of P_2O_5 was applied by hand on the rows after planting.

Evaluations of phytotoxicity and control were performed 3.5 and 7 weeks after planting. Weeds samples from three 25" x 50" frames thrown at randomin in each plot were taken the fifth week and the numbers and weights of each species was recorded. Plants were harvested 136 days after planting.

Phytotoxicity - As it can be observed in Table 6, all of the compounds used in PPI and preemergence applications were selective for soybeans since only very low toxicity scores were registered. Symptoms were leaf burning and discoloration but they had disappeared from most plots five weeks after the applications. Very light symptoms were still evident the fourth week in plants from plots treated with metribuzin 0.75, and with oxyfluorfen 0.5 and 1.0. The symptoms of toxicity had completely disappeared seven weeks after the applications. Of the postemergence treatments acifluorfen 0.75 caused light burning still evident 2 weeks after applications. This symptom had disappeared four weeks after the postemergence treatment was given.

Table 18: Evaluation of Preplant Incorporated (PPI) and postemergence herbicides Lajas 1979.

Degree of injury and percent control and yield respectively

	Injury		Percentage Control		Yield
	July 2	July 12	July 2	July 12	Kg/h
1. Trifluralin	1.3	0.7	75	68	1,319
2. Profluralin	1.0	0.3	82	73	1,401
3. Penoxalin	1.0	0.0	70	67	1,522
4. Trifluralin / Metribuzin	1.0	0.7	82	72	1,603
5. Dalapon		2.3		77	1,418
6. Bentazon / Glyphosate		0.0		8	1,751
7. Bentazon		0.0		10	1,482
8. Oxyfluorfen		1.7		37	1,359
9. Oxyfluorfen		3.3		70	1,686
10. Acifluorfen		1.7		65	1,561
11. Acifluorfen		2.7		80	1,646
12. Methazole		1.7		67	1,447
13. Methazole		2.0		70	1,336
14. HOE 23408		0.0		12	1,298
15. Glyphosate		2.0		93	1,618
16. Oxyfluorfen / Paraquat		1.0		83	1,407
17. Acifluorfen / Paraquat		0.7		82	1,445
18. HOE 23408 / Linuron		0.0		67	1,546
19. Handweeded		0.0		100	1,698
20. Unweeded		0.0		00	1,304

1/ 0 = No injury, 10 = complete kill
Date of planting and application of PPI treatments June 8, 1979
Date of application of postemergence treatments July 2, 1979
Handweeding control cleaned June 28 and July 11
Date of harvesting October 29, 1979

Table 19: Evaluation of preemergence applied herbicides. Lajas 1979.

Weed numbers and weights 30 days after planting in .375 m^2.

		Weed Number				Weed Weight			
		A[1/]	B	C	Total	A	B	C	Total
1. Alachlor	2.0	7.7	4.6	3.3	15.6	264.3	14.9	17.0	296.2
2. Metolachlor	2.0	13.0	7.0	24.9	44.9	443.4	12.8	57.0	513.2
3. Oryzalin	1.0	14.0	24.6	24.0	62.6	468.0	77.8	74.7	620.3
4. Metribuzin	0.5	7.7	1.0	0.7	9.4	163.6	3.2	0.3	167.1
5. Linuron	1.0	13.3	13.0	12.0	38.3	384.1	40.8	21.5	446.4
6. Oxyfluorfen	1.0	1.3	1.3	0.3	2.9	14.3	2.2	0.5	17.0
7. Alachlor / Metribuzin	2.0 / 0.5	7.0	1.0	0.0	8.0	152.9	0.5	0.0	153.4
8. Oryzalin / Metribuzin	1.0 / 0.5	5.3	6.7	5.0	17.0	61.2	19.6	10.6	91.4
9. Metolachlor / Metribuzin	2.0 / 0.5	6.3	3.3	5.3	14.9	202.5	4.2	11.9	218.6
10. Alachlor / Oxyfluorfen	2.0 / 0.5	1.3	8.3	1.3	10.9	21.3	17.2	3.7	42.2
11. Handweeded		---	2.7	1.7	4.4	---	0.8	1.6	2.4
12. Unweeded		33.3	22.3	67.3	122.9	719.3	54.9	92.5	866.7

[1/] A - Johnsongrass (*Sorghum halapense*)
B - Jungle Rice (*Echinochloa colonum*)
C - Nutsedge (*Cyperus rotundus*)

Table 20: Soybean herbicide evaluation. Isabela 1979.

Degree of injury and percent control at 3, 4, 5 and 7 weeks after planting.

	Injury			Control			
	July 16	July 23	July 30	July 16	July 23	July 30	August 14
1. Trifluralin	0.0	0.0	0.0	50	47	40	35
2. Trifluralin / Metribuzin	0.3	0.0	0.0	57	48	35	33
3. Metribuzin	0.6	0.0	0.0	42	45	27	25
4. Metribuzin	0.3	0.0	0.0	60	67	52	50
5. Metribuzin	1.0	0.6	0.0	72	78	73	60
6. Linuron	0.3	0.0	0.0	50	57	50	50
7. Alachlor	0.3	0.0	0.0	70	72	57	47
8. Metolachlor	0.6	0.0	0.0	57	55	50	50
9. Oxyfluorfen	1.0	0.3	0.0	93	88	83	82
10. Oxyfluorfen	1.3	1.0	0.0	95	95	93	87
11. Linuron / Alachlor	0.3	0.0	0.0	68	75	58	57
12. Oxyfluorfen / Alachlor	1.0	0.0	0.0	93	90	85	78
13. Oxyfluorfen / Trifluralin	0.0	0.3	0.0	72	75	58	52
14. Alachlor / Bentazon	0.0	0.0	0.0	43	67	67	47
15. Alachlor / Acifluorfen	0.0	2.3	0.8	47	93	92	90
16. Bentazon	---	0.0	0.0	---	67	62	55
17. Acifluorfen	---	0.3	0.0	---	73	67	65
18. Acifluorfen	---	2.7	1.0	---	90	88	80
19. Metolachlor / Metribuzin	0.0	0.0	0.0	78	75	57	43
20. Handweeded	0.0	0.0	0.0	100	100	100	100
21. Unweeded	0.0	0.0	0.0	0	0	0	0

1/ 0 = no injury; 10 = complete kill

Table 21: Soybean herbicide evaluation, Isabela 1979.

Weed number and weed weight by species in .375 m^2 at four weeks from planting.

Treatments			Weed Number				Weed Weight				Yield
No. Herbicide	Rate Kg a.i/ha	Time of Application	A[1/]	B	C	Total	A	B	C	Total	Kg/ha
1. Trifluralin	1.5	PPI[2/]	239.7	21.3	9.0	270.0	166.5	4.0	19.0	189.5	1025.9
2. Trifluralin / Metribuzin	1.0 / 0.5	PPI	243.0	17.3	10.4	270.7	138.0	4.7	8.4	151.1	1484.6
3. Metribuzin	0.5	PPI	189.3	40.0	11.7	241.0	142.0	10.6	9.5	162.1	1252.4
4. Metribuzin	0.5	Preem	137.0	56.3	23.7	169.6	43.5	12.7	3.0	59.2	1406.3
5. Metribuzin	0.75	Preem	71.0	52.7	30.3	154.0	25.5	10.0	11.5	47.0	1237.9
6. Linuron	1.5	Preem	167.0	61.7	35.3	264.0	53.6	13.7	12.5	79.8	1303.9
7. Alachlor	2.0	Preem	92.7	42.5	8.8	144.0	35.4	8.3	23.6	67.3	1174.8
8. Metolachlor	2.0	Preem	192.7	62.3	8.0	263.0	113.6	13.5	2.0	129.1	1334.4
9. Oxyfluorfen	0.5	Preem	24.7	4.7	4.2	33.6	8.7	1.0	4.2	13.9	1285.6
10. Oxyfluorfen	1.0	Preem	6.0	3.3	3.7	13.0	1.2	0.6	6.2	8.0	1391.8
11. Linuron / Alachlor	1.0 / 1.5	Preem	188.0	28.0	4.0	220.0	83.1	4.3	7.0	94.4	1368.7
12. Oxyfluorfen / Alachlor	0.5 / 1.5	Preem	48.3	1.7	10.7	60.7	10.2	1.8	0.8	12.8	1404.3
13. Oxyfluorfen / Trifluralin	0.5 / 1.0	PPI	159.3	20.3	6.9	186.5	99.5	5.8	3.1	108.4	1520.7
14. Alachlor / Bentazon	1.5 / 1.0	Preem / Post	237.0	23.7	5.0	265.7	141.1	7.5	7.0	155.6	1320.6
15. Alachlor / Acifluorfen	1.5 / 0.75	Preem / Post	24.0	13.3	8.0	45.3	4.5	3.1	3.4	11.0	1395.9
16. Bentazon	1.5	POST	67.7	63.3	19.0	150.0	18.1	15.2	21.1	54.4	1267.8
17. Acifluorfen	0.5	POST	115.0	55.0	7.7	177.7	48.6	13.4	9.5	71.5	1502.4
18. Acifluorfen	0.75	POST	55.3	22.3	15.3	93.0	11.6	3.1	4.1	18.8	1363.7
19. Metolachlor / Metribuzin	1.5 / 0.5	Preem	119.3	36.7	5.6	161.6	64.7	11.0	2.5	78.2	1479.6
20. Handweeded			35.7	25.3	4.7	65.7	9.6	4.4	2.6	16.6	1655.0
21. Unweeded			225.7	24.7	33.3	283.7	101.1	8.1	10.6	119.8	1057.1

[1/] A = wild poinsettia (*Euphorbia heterophylla*), B = woodsorrell (*Oxalis intermedia*), and C = annual grasses (*Echinochloa colonum* and *Eleusine indica*).

Weed control - More than 70% control, four weeks after the preemergence or one week after the postemergence applications, was registered in increasing order of effectiveness by alachlor 2.0 preemergence; acifluorfen 0.5 postemergence; linuron 1.0 plus alachlor 1.5; oxyfluorfen 0.5 + trifluralin 1.0 PPI; metolachlor 1.5 + metribuzin 0.5 preemergence; metribuzin 0.75 preemergence; oxyfluorfen 0.5 preemergence; oxyfluorfen 0.5 plus alachlor 1.5, alachlor 1.5 preemergence plus acifluorfen 0.75 postemergence and oxyfluorfen 1.0 preemergence.

Best control (78 to 90% control), seven weeks after the application of the PPI and preemergence treatments and four weeks after given the postemergence applications, was provided by the following treatments in increasing order of efficacy; oxyfluorfen 0.5 plus alachlor 1.5 preemergence; acifluorfen 0.75 postemergence; oxyfluorfen 0.5 preemergence; oxyfluorfen 1.0 preemergence and alachlor 1.5 preemergence plus acifluorfen 0.75 postemergence.

Lower weed counts (Table 7) at four weeks from planting were obtained with 1. oxyfluorfen 1.0 preemergence; 2. oxyfluorfen 0.5 preemergence; 3. alachlor 1.5 preemergence plus acifluorfen 0.75 postemergence, 4. oxyfluorfen plus alachlor 0.5/1.5 preemergence and 5. acifluorfen 0.75 postemergence.

Lower weed weights were registered in the plots treated with 1. oxyfluorfen 1.0; 2. alachlor 1.5 preemergence; plus acifluorfen 0.75 postemergence; 3. oxyfluorfen 0.5 preemergence; 4. acifluorfen 0.75 postemergence; 5. bentazon 1.5 postemergence; metribuzin 0.75 preemergence; 6. metribuzin 0.5 preemergence.

It seems from this and the Lajas herbicide trials that the compounds oxyfluorfen and acifluorfen may be added to the list of selective compounds that provide adequate control of weeds commonly associated with soybeans in the tropics, some of them like morning glory not satisfactorily controlled by presently recommended compounds.

Glyphosate weed control with and without land preparation., Lajas, 1979.

Johnsongrass is a common troublesome weed in tropical and subtropical areas where it causes high crop yield losses. It has been observed in previous trials performed under the grant that soybean yield can be reduced by over 50% when Johnsongrass is not adequately controlled.

The present experiment was established to compare the effect of land preparation and glyphosate applications on Johnsongrass control. Part of a field densely infested with Johnsongrass was plowed once and disked twice and part was left unprepared. Plots of 10 by 3 m were marked in both sides. Johnsongrass in half of the plots of the nontilled side was cut by hand. Glyphosate at a rate of 1 Kg acid equivalent per hectare, was applied to all the nontilled plots one week after cutting on June 13th.

Soybean cultivar Improved Pelican was planted on June 19th in

all but four of the tilled plots where Johnsongrass was allowed to resprout. These plots were treated with glyphosate and planted on June 2nd. All but 4 plots were treated with a combination of alachlor 1.5 plus metribuzin 0.5 immediately after planting. These plots only received 2 handweeding at 4 and 7th week after planting.

Treatments given were:

1. Nontilled + Glyphosate 1.0 + preemergent herbicide
2. Nontilled + cutting + glyphosate + preemergent herbicide
3. Conventional tillage + glyphosate at sprouting + preemergent
4. Conventional tillage + Glyphosate 1.0 postemergent directed spray + preemergent
5. Conventional tillage + Glyphosate 1.0 with paint roller + preemergent
6. Conventional tillage + cutting at 5 weeks + preemergent
7. Conventional tillage + preemergent
8. Handweeding at 3 and 6 weeks after planting

The results obtained with these treatments are shown below:

Table 22: Glyphosate weed control with and without land preparation. Lajas, 1979.

Weed number and counts in .375 m^2 at 4 weeks from planting, % Johnsongrass control at 8 weeks and yield.

Treatment No.	Weed Number					Weed Weight					% A Control 8 weeks	Yield Kg/h
	A[1/]	B	C	D	Total	A	B	C	D	Total		
1	0	3	27	9	39	0	2.3	17.8	15.4	35.5	95	1270.8
2	0	1	12	10	23	0	0.5	10.2	18.2	28.9	95	1356.9
3	7	4	2	0	13	96.1	2.7	1.4	0.0	100.4	60	746.0
4	6	3	1	0	10	99.5	7.4	1.1	0.0	108.0	75	1051.0
5	3	7	0	0	10	23.7	13.6	0.0	0.0	37.3	92	931.1
6	10	13	1	1	25	119.5	25.2	0.9	7.9	153.5	86	1116.4
7	8	3	0	0	11	88.2	4.6	0.0	0.0	92.8	90	1212.5
8	0	7	0	0	7	0	9.3	0.0	0.0	9.3	94	1040.5

1/A - *Sorghum halepense*
B - *Cyperus rotundus*
C - *Echinochloa colonum*
D - Others

No symptoms of toxicity due to any of the herbicide treatments was observed in the evaluations performed one month after the applications. At the same date it was evident that the area covered with annual weeds was greater in the nontilled plots in which the vegetation was killed with glyphosate than in the tilled plots. More annual weeds developed in the cut plots than the uncut ones. This observation seems to indicate that the action of the pre-emergence herbicides was reduced by the presence of crop residues. Control of Johnsongrass was complete in the plots treated with glyphosate either cut, uncut or at regrowth.

The evaluation performed at 8 weeks after the beginning of the experiment showed that control of Johnsongrass was still almost complete in the non-tilled plots treated with glyphosate. Control of Johnsongrass in the plots treated with glyphosate after preparation allowing its regrowth was deficient at this time in spite they were treated with preemergence herbicide which controlled seedlings, rhizomes sprouting after the treatments were responsible for the reinfestation. It seems from this trial that treatment of Johnsongrass plants before plant preparation provides more affective and lasting control than treatment after disturbance by land preparation. Treatment of Johnsongrass plants with glyphosate applied with a paint roller provided good control in the furrows but not in the rows. It seems that higher doses of preemergence herbicides are required for effective control of annual weeds when Johnsongrass plant residues are present in the plots.

Higher yields were obtained in the nontilled plots where Johnsongrass was cut and treated with glyphosate and with an application of metribuzin plus alachlor .5/1.5 (Table 22).

II. Education and Training

A major objective of this grant is to use the expertise of major researchers for strengthening education and training at the University of Puerto Rico, Mayaguez in crop protection. Grant support has helped stimulate the formation of the Crop Protection Department which currently employs 56 scientists (26 at Ph.D level and 30 at the B.S. or M.S. levels). The new department integregates plant pathology, nematology, entomology, weed science and pesticide usuage under one program.

Courses which have been incorporated into the teaching program by grant staff include: 1) Diagnosis and control of plant diseases 2) Concepts in phytopathology 3) Weed control 4) Physiology of Herbicide Action 5) Control of Phytoparasitic Nematodes 6) Tropical Agronematology and 7) Phytopathogenic Fungi. A total of more than 20 courses are taught under the Department of Crop Protection. Clearly the grant staff has had a significant effect in developing this program.

More than 25 graduate students are currently enrolled in the Department of Crop Protection. The two laboratory facilities which were developed under this grant are primary work centers for over 25% of these students and serve others for a portion of their research and in their teaching.

Graduate students currently doing research relevant to grant objectives are:

1. Americo Celada from the Peruvian national soybean program and is working with Dr. Guillermo Riveros on the effect of soybean spacing and density on weed growth.

2. Otoniel Mendoza from Peru who is working with Dr. Riveros in increasing the selectivity of metribuzin as a soybean herbicide.

3. Juan Mendoza from Honduras who is working with Dr. Julia Mignucci on the assessment of disease losses by soybean anthracnose.

An excellent student exchange was developed between University of Illinois and University of Puerto Rico stimulated by cooperative ties established under INTSOY. International and tropical experience has enriched the student and student generated research helps solve tropical production problems.

As an example Glenn Bowers (UIUC) has done a major portion of his graduate studies utilizing field facilities at Isabela, Puerto Rico. Soybean mosaic virus (SMV) which he is studying can be better studied in Puerto Rico because conditions favor high incidence and damage and growing season isn't limited.

Results from Glenn's work will be helping control SMV in tropics since he has identified the sources and inheritance of SMV resistance.

III. Increasing advisory capability by developing a coordinated and interdisciplinary team of researchers with expertise in the protection of soybean and other grain legumes.

The capability to advise is heavily dependent and related to travel expenditures. To serve in the advisory capacity a broad knowledge of the current status of developments in crop protection is needed. Besides participating in international short courses and as consultants, grant staff has participated annual meetings of their respective societies. A compilation of travel for the last grant year is following (Table 23). Participation of this type is prerequisite for maintaining and developing advisory capacity.

IV. Expanding research and information linkages.

The expansion of research and information through linkages is an important criteria for realizing the full effect of research efforts. Linkages have been established between this project and:

a. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyberadad, India.
b. Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia.
c. Instituto Colombiano Agropecuario (ICA), Colombia
d. Instituto Interamericano Ciencias Agrícolas, (IICA), Costa Rica
e. Instituto Nacional de Investigaciones Agropecuarias (INIAP), Quito, Ecuador.
f. Universidad de Panamá, Panamá
g. International Institute for Tropical Agriculture (IITA), Ibadan, Nigeria
h. Centro Internacional de la Papa (IP), Lima, Perú
i. Ministerio de Alimentación, Lima, Perú
j. Asian Vegetable Research and Development Center (AVRDC), Taiwan

on an international level. On the national level, linkages are established with the Mayaguez Institute of Tropical Agriculture, Agriculture Research Service, U.S.D.A., Beltsville, Iowa State, North Carolina State, and other U.S. universities. The need for international and national linkages is mandated by the geographic and economic scope of crop protection problems. Seldom is local approach most effective.

The research results are most stimulating and available when formally presented or published. Publications support

the expertise of researchers and their attractiveness as consultants. Some of grant staff presentations and publications related to soybean crop protection and other publications which were partially or fully supported by grant funds are given.

Table 23: Compilation of Travel under 211(d) Soybean Project during the last grant period

Researcher	Destination	Period	Organization	Output
N. Acosta	Charleston, South Carolina	June 10-14, 1979	Annual Meeting Organization of Tropical American Nematologists (OTAN)	"Resistance of soybean cultivars to *Pratylenchus* spp. and *Meloidogyne* sp."
N. Acosta	Raleigh, North Carolina	Mar. 26-29, 1979	World Soybean Research Conference	Update on soybean research. Linkage made with other soybean researchers.
M. A. Ellis	Washington, D.C.	Aug. 5-12, 1979	IXth International Congress of Plant Protection	"Integrated pest management of soybean - plant pathogens".
M. A. Ellis	Cali, Colombia	Apr. 28 - May 6, 1979	2nd Seed Technology Training Course for Latin America	"Control of Seedborne Pathogens". "Microbial Acitivity and Seed Quality".
M. A. Ellis	Raleigh, North Carolina	Mar. 26-29, 1979	World Soybean Research Conference	"Influence of soybean seedling vigor on nodulation". "Effect of pod inoculation with *Phomopsis* sp. on seed germination of two cultivars".
M. A. Ellis	Santo Domingo, Dominican Republic	Feb. 17-24, 1979	Expert Consultation on Production of Food Legumes in the Caribbean	
M. A. Ellis	Tucson, Arizona	Oct. 28 - Nov. 3, 1978	Annual Meeting American Phytopathological Society	"Variation in the reaction of two soybean cultivars to seed infection by *Phomopsis* sp." "Effect of foliar fungicides on internally-borne fungi, germination, and emergence of late-harvested cowpea seeds".

Researcher	Destination	Period	Organization	Output
P. R. Hepperly	Washington, D.C. University Park, Pennsylvania	Aug. 4-17, 1979	IXth International Congress of Plant Protection and Fusarium Short Course	Linkage with AID training representative. Update on Crop Protection and *Fusarium* identification.
G. Riveros	Kingston, Jamaica	May 16-19, 1979	Consultation AID, Kingston Office	Herbicide and other weed control practices recommended for Jamaican conditions on soybean
G. Riveros	San Francisco, California	Feb. 5-11, 1979	Annual Meetings of the American Society of Weed Science	Update on weed research, linkages made with other weed researchers.
G. Riveros	Raleigh, North Carolina	Mar. 26-29, 1979	World Soybean Research Conference	Update on soybean research, linkages made with other soybean researchers.

Table 24: A Partial List of Grant Related Presentations, Publications and Theses

Acosta, N. 1979. Susceptibility of soybean cultivars to *Pratylenchus scribneri* and *Meloidogyne incognita*. NEMATROPICA 9:96 (Abstr.)

Acosta, N., R. B. Malek, and D. I. Edwards. 1979. Susceptibility of soybean cultivars to *Pratylenchus scribneri*. J. Agric. Univ. P.R. 63:103-110.

Acosta, N. 1978. Histopathology of *Pratylenchus scribneri* and *P. alleni* on soybean roots. NEMATROPICA 8:1 (Abstr.)

Acosta, N. and R. B. Malek. 1979. Influence of temperature on population development of eight species of *Pratylenchus* on soybean. J. Nematol. 11:229-232.

Acosta, N. 1978. Host-Parasite relationships of lesion nematodes, *Pratylenchus* Filipjev. spp., and soybean *Glycine max* (L.) Merr. Dissert. Abstr, International 38(10):4563.

Acosta, N. and R. B. Malek. 1979. Influence of inoculum level and temperature on pathogenicity and population development of *Pratylenchus alleni* and *P. scribneri* on *Glycine max* (Manuscript).

Acosta, N. 1979. Influence of time on population dynamics of *Pratylenchus alleni* and *P. scribneri*. (Manuscript)

Acosta, N. 1979. Distribution of *Pratylenchus alleni* and *P. scribneri* in soybean roots. (Manuscript)

Arrieta, J. 1976. Studies on pathogenicity and control of phytoparasitic nematodes of soybean (*Glycine max* (L.) Merr.) in Puerto Rico. Master's Thesis, University of Puerto Rico.

Backman, P. A., J. M. Hammond, and M. A. Ellis. 1978. Peanut seed treatment trials, 1977. Fungicide and Nematicide Test 33:164.

Cuebas, F. 1977. Mutagenic specificity of 5-bromodeoxyoridine in germinating soybean (*Glycine max* (L.) Merr.) seeds. Master's Thesis, University of Puerto Rico.

Ellis, M. A., P. R. Hepperly, S. R. Foor, and E. H. Paschal. 1977. Seed treatment of pigeon pea with fungicides, antibiotics, and dichloromethane. Fungicide and Nematicide Tests 32:177-178.

Ellis, M. A., P. R. Hepperly, E. H. Paschal, and S. R. Foor. 1977. Soybean seed treatment with fungicides, antibiotics and certain solvents under tropical conditions, 1976. Fungicide and Nematicide Test 32:189-190.

Ellis, M. A., E. H. Paschal, and P. Powell. 1977. The effect of maturity and foliar fungicides on pigeon pea seed quality. Plant Dis. Reptr. 61: 139-143.

Ellis, M. A., and E. H. Paschal. 1977. Factors affecting pigeon pea seed quality in Puerto Rico. Mem. Soc. Puertorriqueña Cien. Agri. 2:2 (Abstr.)

Ellis, M. A., O. Zambrano, and E. Rosario. 1977. Internally seedborne fungi of four leguminous crops in Puerto Rico. Mem. Soc. Puertorriqueña Cien. Agri. 2:7 (Abstr.)

Ellis, M. A., and E. H. Paschal. 1978. Effect of fungicide seed treatment on internally seedborne fungi, germination, and field emergence of pigeon pea (*Cajanus cajan*). Seed Sci. and Technol. (In press)

Ellis, M. A., E. H. Paschal, E. Ravalo, and E. Rosario. 1978. Effect of growing location on internally seedborne fungi, seed germination, and field emergence of pigeon pea in Puerto Rico. J. Agr. Univ. of P. R. 62:355-360.

Ellis, M. A. and R. S. Smith. 1978. Effect of incubation temperature on recovery of internally seedborne fungi and germination of pigeon pea seeds. Tropical Grain Legume Bulletin 13&14:22-25.

Ellis, M. A., R. S. Smith, and E. J. Ravalo. 1978. Effect of moisture content, storage container and temperature on pigeon pea seed storage in Puerto Rico. Proceedings American Society of Agronomy (Abstr.) 146.

Ellis, M. A., O. Zambrano, and E. H. Paschal. 1978. Evaluation of seed treatment compounds on good and poor quality seed under tropical conditions, 1977. Fungicide and Nematicide Tests 33:173.

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Ellis, M. A., J. Oard, and R. S. Smith. 1979. Evaluation of seed treatment compounds on four soybean cultivars of varying seed quality, 1978. Fungicide and Nematicide Tests 34:171-172.

Ellis, M. A., E. H. Paschal, P. E. Powell, and F. D. Tenne. 1979. Internally seedborne fungi of soya bean in Puerto Rico and their effect on seed germination and emergence. Tropical Agric. 56:171-174.

Ellis, M. A., E. J. Ravalo, and R. S. Smith. 1979. Methods for pigeon pea storage in Puerto Rico. J. Agric. Univ. P. R. 63:423-427.

Ellis, M. A., R. S. Smith, and J. B. Sinclair. 1979. Effect of fungicide seed treatment on field emergence of poor and good quality pigeon pea (*Cajanus cajan*). J. Agric. Univ. P. R. 63:8-12.

Ellis, M. A., and O. Zambrano. 1979. Effect of pod inoculation with *Phomopsis* sp. on seed germination of two soybean cultivars. World Soybean Research Conf. 85 (Abstr.)

González, J. A. 1977. Effect of the amount of inoculum on the epidemiology of purple seed stain disease of soybean. Master's Thesis, University of Puerto Rico.

Hannía, Cesar. 1978. Control of root-knot nematode (*Meloidogyne* spp.) on soybeans. Master's Thesis, Univ. of Puerto Rico.

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Hepperly, P. R. and J. B. Sinclair. 1978. Soybean seed treatment, 1977. Fungicide and Nematicide Test 33:175.

Hepperly, P. R. and J. B. Sinclair. 1978. Distribution of *Phomopsis* - infected seeds on field-grown soybeans. Phytopathology News 12:88 (Abstr.).

Hepperly, P. R. and J. B. Sinclair. 1978. Quality losses in *Phomopsis* - infected soybean seeds. Phytopathology 68:1684-1687.

Hepperly, P. R., G. R. Bowers, and J. B. Sinclair. 1978. Increased *Phomopsis sojae* and reduced seed quality associated with soybean mosaic virus infected soybean plants. Third International Congress of Plant Pathology p. 125 (Abstr.)

Hepperly, P. R., M. C. Shurtleff, B. J. Jacobsen, and J. B. Sinclair. 1978. Pod and stem blight of soybean. University of Illinois, Dept. of Plant Pathology, Report on Plant Diseases No. 509.

Hepperly, P. R. 1979. *Phomopsis sojae*: colonization of hosts, interactions with other pathogens, and losses on soybeans. Ph.D Thesis, Univ. of Illinois, Urbana 96 pp.

Hepperly, P. R. 1979. INTSOY and Soybean seed pathology in Puerto Rico. Invitational seminar for Dept. of Agronomy, UPR, Mayaguez, September 1979.

Hepperly, P. R., and J. S. Mignucci. 1979. Incidence of *Colletotrichum dematium* on soybean in Puerto Rico. Mem. Soc. Puertorriqueña Cien. Agr., 6 (Abstract)

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Paschal, E. H., and M. A. Ellis. 1979. Identification of soybean genotypes with superior seed quality. World Soybean Research Conf. 71 (Abstr.)

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Riveros, G. 1976. Importance of weed control in tropical soybeans. INTSOY Series No. 10:65-73.

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Riveros, G. 1980. Herbicide Screening for four grain legumes in Puerto Rico. J. UPR 64: (In review).

Salaues, E. 1978. Efectos de fotoperiodo en las características fenológicas de cultivares de soya (*Glycine max* (L.) Merr.) cultivados en diferentes epocas. Master's Thesis, University of Puerto Rico.

Smith, R. S., M. A. Ellis, and M. Z. Alameda. 1978. Influencia del vigor de la planta de soya en la nodulación. IX Reunion Latinoamericana Sobre Rhizobium (Proceedings) 83-92.

Smith, R. S., and M. A. Ellis. 1980. Soybean nodulation as influenced by seedling vigor. Agron. J. 72: (Accepted for publication).

Smith, R. S., and M. A. Ellis. 1979. Influence of soybean seedling vigor on nodulation. World Soybean Research Conference p. 12 (Abstr.).

Tuesta, H., A. Sotomayor-Ríos and G. Riveros. 1979. Efectos del cultivo intercalado de tres variedades de soya con tres híbridos de maíz en los rendimientos del grano y sus componentes. Mem. Soc. Puertorriqueña Cien. Agri. 19 (Abstr.).

Zambrano-Medranda, O. 1978. Efecto de los hongos sobre la calidad de la semilla de soya en Puerto Rico y algunas medidas para su combate. Master's Thesis, University of Puerto Rico.

V. Impact of Grant - Supported Activity in Achieving Grant Purpose

There is no question that grant funding has had a positive effect in developing UPR/MC institutional response capability in the tropical crop protection and production of soybean and other food legumes. Grant supported activities are an integral part of the Department of Crop Protection. The Department has demonstrated it's keen interest in contributing to the grant program.

The grant has had a profound effect on the teaching program within the college of agricultural sciences and the Department of Crop Protection. Staff personnel have been active in the development of the curriculum for the new department and three grant supported staff members are currently teaching courses at the graduate level. Through providing new and improved laboratory facilities, audiovisual equipment, increased library resources and increased staff personnel, the grant has enhanced the quality of teaching at UPR/MC. At present, 25 graduate students are working toward the M.S. degree in Crop Protection and the number of students developing interest in the field is continually increasing.

Teaching and research facilities have been significantly improved under this grant. New laboratory facilities, including greenhouses, have been developed at the College Farm (La Finca). These facilities are currently available to staff and students. Laboratory facilities on campus for plant pathology and nematology have also been developed and made available to staff and students. The development of these facilities has had a direct effect upon the development of UPR/MC institutional response capability. At present, UPR/MC is capable and willing to provide education, training, and consultation to LDC's of the tropics in protection and production of soybean and other food legumes.

Grant funds have been used to provide travel support for staff members. This provides two major benefits for the institution and the program: 1) the broadening of professional experience and expertise and 2) the development of linkages and establishment of new joint research projects.

VI. Other Resources for Grant Related Activities

Funds provided under this grant have never been used to replace existing funds for other university projects. Activities conducted under this grant have been designed to compliment and strengthen existing programs.

In direct support to the grant, UPR/MC has provided and will continue to provide:

1. Administrative costs including salaries and utilities in administrative offices.

2. Class rooms, library, field space and facilities, office space, and laboratory space and utilities have also been provided to grant personnel by UPR/MC. All facilities available through the Agricultural Experiment Station have been made available to grant personnel and grant related activities. The services of the Central Analytical Laboratory of the Agricultural Experiment Station, the soil testing laboratory at the Mayaguez campus and the Nuclear Center have also been made available to grant personnel and projects at no charge to the project. These costs (contributions) are very difficult to assess. They are roughly equivalent to the overhead charges for a research contract.

In order to develop institutional response capability in the area of tropical crop protection of soybean and other food legumes, UPR/MC has spared no expense and has always given 100% support to the program developed under this grant.

No other sources of funding have been made available to this program.

VII. Utilization of Institutional Response Capabilities in Development Programs

Through the development and demonstration of UPR/MC response capability, the number of requests for assistance has significantly increased during the reporting period and it is anticipated that the number of requests will continue to increase as interest in the tropical production of soybean increases.

VIII. Plan of Work

Since the inception of this grant first priority has been given to the development of a strong research program and the establishment of education and training facilities and staff in the area of tropical crop protection of soybean and other food legumes. This priority ranking will be slightly changed for the remainder of the funding period. Future program emphasis will be placed on the utilization of developed institutional response capabilities in development programs.

The continuation of the on going research program will maintain a position of high priority in the last year of the grant. The maintenance of a high quality research program provides the following primary functions:

1) the development of needed technology in the area of tropical crop protection of soybean;
2) the continued development of staff expertise and knowledge in the problem area; and
3) the demonstration of UPR/MC institutional response capability in the problem area.

Dr. Nelia Acosta has recently received her Ph.D in nematology at UIUC. Dr. Acosta was involved in the grant supported student exchange program between UPR/MC and UIUC. Her return to UPR/MC has facilitated the incorporation of the nematology component into the present program. The development of response capability in tropical nematology of soybean has received funding in year V of the grant and will continue to receive funding under the grant. Dr. Acosta has initiated research in control of nematodes in soybean under tropical conditions.

The last year of grant extension will see a change in personnel. Dr. Mike Ellis who found other employment is being replaced by Dr. Paul Hepperly as grant director and seed pathologist. Dr. Pedro Meléndez has assumed administrative responsibility as head of the Crop Protection Department and will no longer work under the grant. Eileen Rosario who gave laboratory assistance is currently working for Bacardi. The grant has incorporated Dr. Julia Mignucci at 20% of time to develop foliar disease expertise. The staff feels that soybean rust research should develop on an international scale to prevent the large losses if it is introduced to the United States. Puerto Rico as an area where rust is endemic but lacking a commercial soybean crop is likely center of such research. Dr. Mignucci has expertise in handling obligate parasites from her experience with soybean powdery mildew. Her addition is seen as a on going committment to solving the major pest problems of soybeans.

Continued development and maintenance of facilities for research and training will receive program support and funding. Of special interest to this program, is the establishment and continued development of the newly founded Department of Crop Protection.

Full program support will be given to pertinent graduate student research. In addition, A.I.D. has provided funding for two graduate assistantships. Assistantships will be provided within the Department of Crop Protection for research on tropical crop protection of soybean.

Continued development of informational research and informational linkages will be supported. In all grant related activities, our primary linkage with UIUC will be continued. UIUC has truly distinguished itself as the leading institution in world soybean development. Through cooperation and planning with UIUC and other linked institutions and organizations, the basis for a truly international network of organizations and individuals which can sustain future soybean development programs for the tropics has been developed.

As funding permits, all requests for assistance from LDC's will be answered.

The development of literature (in Spanish and English) based on

current knowledge and results from program research will receive funding during the last year of the grant.

IX. Involvement of Minority Personnel and Women

The University of Puerto Rico is an affirmative action, equal opportunity employer.

The grant has funded qualified women at all levels of employment. Currently, the program secretary, nematologist and foliar pathologist are women.