Evaluation Issues for Multi-Project Research Activities: An Application of *Rhizobium* Research in the Philippines*

*Tirso B. Paris Jr., Nora Dm. Carambas and Jeff S. Davis***

1. Introduction

This paper is based on an on-going study at the University of the Philippines Los Baños (UPLB) as part of the research program entitled "Economic Evaluation of the University of the Philippines at Los Banos (UPLB)/Australian Collaborative Projects Funded by ACIAR". Among others, the project attempts to undertake detailed project level evaluations of the impact of completed and current projects with research groups at UPLB. These evaluations attempt to estimate the welfare impacts of the projects on all groups in the Philippines, including any environmental impacts, and other countries in the region if applicable.

One group of projects being evaluated is the research on the development of *Rhizobium* inoculants in the Philippines. Australian and Filipino researchers have worked jointly under three ACIAR-funded collaborative *Rhizobium* research projects (PN 8574, PN 8731, and an ongoing small project). PN 8574 (Ecology of Rhizobium in the Philippines) and PN 8731 (Biological Nitrogen Fixation in Food and Tree Legume Production Systems in the Philippines) were completed in 1987 and 1990, respectively. The small project is due to be completed by March 1996.

For food legumes, the main objectives of the ACIAR/UPLB projects are to assess the requirements for Rhizobium inoculation of soybean and mungbean; to develop suitable inoculants and methods of application; to assess inoculum build up in soil and the requirement for continued inoculation; to select Rhizobium strains and cultivar combinations especially adapted to acid soils; to determine nutrient and soil fertility amendments to maximise biological nitrogen fixed by these legumes under field conditions; and to estimate the amount of nitrogen fixed by soybean and mungbean under field conditions and made available to subsequent crops.

This project presents an interesting case for project level evaluations for several reasons. First, the technology generated, namely the Rhizobium inoculants for several food legumes, specifically soybean and mungbean, was a product of a series of related research projects, of which the UPLB/ACIAR collaborative research projects was a part. Second, there was a significant research lag where benefits from the use of inoculants started sometime in 1982 when they were first introduced to farmers, although the research process over 10 years before the start of dissemination of the technology. This feature appears to be common to many other projects and presents some special methodological problems in evaluation.

---

* Paper presented at the 40th Annual Conference of the Australian Agricultural and Resource Economics Society (AARES), Melbourne, Australia, 13-15 February 1996.

** Project Leader and Professor , University of the Philippines Los Banos; Research Associate, University of the Philippines Los Banos; and Project Leader and Head, Economics Evaluation Unit, Australian Centre for International Agricultural Research, respectively.

The purpose of this paper is to review the various aspects of the project level evaluation on the Rhizobium projects. Particular emphasis is given on the research lag in technology development and the apportionment of the benefits of the overall research effort attributable to a subset of the research.

2. Rhizobium Research for Legumes in the Philippines

The *Rhizobium* Research and Development Continuum

The currently existing *Rhizobium* technology for grain legumes in the Philippines evolved through a series of research activities. At the UPLB, studies on *Rhizobium* commenced way back in the 1960's under the Department of Soil Science. *Rhizobium* research projects were then entrusted to the National Institutes of Biotechnology and Applied Microbiology (more popularly known as BIOTECH) in 1980 right after the unit was created.

Funds for studies on *Rhizobium* started to pour in only in the 1970's during which interest in chemical fertiliser substitutes was aroused by the escalating cost of chemical fertilisers due to oil crisis. Funds have come from both local and foreign agencies. Table 1 presents the list of *Rhizobium* research projects that were (or being) undertaken at the UPLB together with their corresponding sources of funds and duration. They numbered 19 in all.

Through the years, works on *Rhizobium* have undergone progression, from basic types of studies to developmental ones. During the early stage, research activities were more concerned on: (1) the development of method of counting the number of *Rhizobia* in the soil and determining their presence in nodules, (2) isolation and purification of *Rhizobia*, (3) testing the competitiveness and effectiveness of *Rhizobium* isolates and selection of the promising ones, and (4) development of inoculants.

In the next stage, several pot experiments and extensive field trials were conducted to determine the following: (1) the response to inoculation of grain legumes under different agroclimatic conditions and cropping systems, (2) the interaction between *Rhizobial* strains and grain legume cultivars, (3) the persistence of inoculum in rice-based cropping system or flooded condition, (4) the optimum rate of inoculation and fertiliser application and the proper timing of the latter, (5) the effective method of inoculum application, i.e. the use of granular soil inoculant versus powdered seed inoculant, and (6) the effectiveness of using *Rhizobium* and vesicular arbuscular (VA) *Mychorrizal* inoculants at the same time. (*Mycorrhiza* is a beneficial association between plants and fungus. *Mycorrhiza* increases absorption of phosphorus and all other nutrients.)

On the other hand, the ongoing *Rhizobium* research projects are geared towards further improvement of the quality of the inoculants that are being produced at the pilot plant. The researchers are now evaluating the potential of various inoculum carriers and stickers. They are trying to find a carrier which could support higher *Rhizobium* population to replace the carrier that they currently use and a sticker which would increase the amount of inoculant adhering to the seeds, extend the longevity of, and provide protection to, the inoculum. The currently existing *Rhizobium* technology uses water only as sticker.

In addition, the researchers are investigating the possibility of coming up with *Rhizobium* inoculants which are fortified with micronutrients such as molybdenum, boron, calcium, and cobalt and *Rhizobium* inoculants which contain VA Mycorrhiza and/or any plant growth promoting rhizobacteria for stress environments such as in acid soils and drought prone areas. The researchers, too, are now in the process of testing in the field the performance of their newly formulated granular and liquid soil inoculants.

Demo trials, video presentation, open forum, and distribution of inoculant sample are currently being undertaken to promote the use of the *Rhizobium* technology.

The Accomplishments Under ACIAR-UPLB Collaborative *Rhizobium* Research Projects

ACIAR has been involved in *Rhizobium* research at the UPLB since 1986. When it came to the fore, researchers at the UPLB had already undertaken substantial works on biological nitrogen fixation by *Rhizobium*. Much had been done as far as *Rhizobial* isolation, purification, and testing for competitiveness and effectiveness were concerned. Moreover, *Rhizobium* inoculants had been produced several years back.

To date, Australian and Filipino researchers have already worked jointly under three ACIAR-funded collaborative *Rhizobium* research projects (PN 8574, PN 8731, and the ongoing project which is just a small one). PN 8574 and PN 8731 were completed in 1987 and 1990, respectively. The small project will be finished come March 1996. PN 8574 and PN 8731, which were primarily concerned with the ecology of *Rhizobia* that nodulate grain legumes particularly mungbean and soybean, had complemented the USAID-funded *Peanut Collaborative Research Support Program*.

Under PN 8574, a total of 366 isolates (98 mungbean isolates and 268 soybean isolates) were collected from different cultivars of mungbean and soybean, that were grown on different soil types in the Philippines, and they were tested for competitiveness and effectiveness.

Several field trials were conducted under the same project with the end in view of determining the response of different soybean cultivars to inoculation with various strains of *Bradyrhizobium* under different environmental conditions. The results showed that soybean cultivars and *B. japonicum* strains performed differently under different environmental conditions. Nonetheless, USDA 110 was found to be highly competitive and effective under most conditions. This finding led to the change in the *Rhizobial* strain that was being used in the pilot production of inoculant for soybean, from CB 1809 to USDA 110.

Another important finding under the project was that nitrogen fertilisation of inoculated plots is not beneficial for it inhibits biological nitrogen fixation. Inoculation alone is sufficient to increase yield significantly.

Under PN 8731 (food legume component), extensive field trials were conducted to determine the response of mungbean to inoculation with different *Bradyrhizobium sp* strains. The field trials were done in key locations, where mungbean is likely to be planted, and under different cropping systems. The results of these trials indicated whether or not mungbean in a particular location/cropping system needs to be inoculated. For instance, it was established from the trials that there would be significant response to inoculation particularly in marginal areas or soils with low nitrogen and in areas not previously planted with legumes.

The project determined the combination of *Bradyrhizobium sp.* strain and mungbean cultivar that would particularly be suited to acid soils. The method of inoculation and the soil amendments that would enhance symbiotic effectiveness of the bacteria in acid soils were also investigated. The results indicated that for acid soils, soil inoculation with granules rather seed inoculation as being commonly done is superior and liming would enhance the benefits from inoculation.

The long-term experiment which was started under PN 8574 was continued under the project to determine the persistence of the bacteria in rice-based cropping system. UPL Sy2 and UPL Sy4 and *B. japonicum* strains CB 1809 and USDA 110 were utilised. Two treatments were applied. In the first, inoculant was introduced only at the initial planting of soybean. In the second one, inoculant was introduced every time soybean was planted after rice. This study showed that regardless of the frequency of inoculation, the proportion of nodules formed by the inoculum strains decreased from 96% in the first soybean crop to 40% in the third crop. The study also showed that the number generally decreased during the rice culture and it took three soybean seasons to establish a large soil population of *B. japonicum*. This particular study led to the recommendation that inoculation must be done every time a legume crop is planted after rice.

Like PN 8574, another important impact of this project was that this led to the change in the strain of *Rhizobium* that was being used in the inoculant production for mungbean at the BIOTECH. Prior to the field trials, the strain being used for mungbean was M5. After the project, BIOTECH shifted to M6 which is also an acid tolerant strain.

The Inoculant Production and Distribution

The production of inoculant in the Philippines has not yet been privatized. This is still being carried out by laboratories under BIOTECH, BSWM (Bureau of Soils and Water Management), and DA-RFU's (Department of Agriculture, Regional Field Units). This kind of setup has met various constraints which hampered full blown production of the inoculant and hence the adoption of the technology by farmers as well.

BIOTECH has a pilot plant whose production capacity (72.28 metric tons per year) can support all food legume farms in the country. It also has well trained personnel to man the production of good quality inoculant. The problem in BIOTECH, however, is that it does not have distribution arms to reach the farmers in the regions. It has been mainly dependent on farmers who personally come to the laboratory to buy inoculant and coordinators of programs on food legumes. For instance, when the government had launched pilot production programs and technology commercialization programs on peanut, mungbean, and soybean, wherein seed inoculation was a component of the package of technology (POT) being commercialized, the coordinators of these programs got inoculants from BIOTECH for distribution to farmer-cooperators of the program. This is the same arrangement happens under the current programs, namely, the *Accelerated Soybean Production and Utilization Program* (ASPUP) and *Lab to Land: Application and Commercialization of Legume Inoculant for Small-Scale Farmers*.

Nestle Philippines, Inc. used to be the Biotech's biggest buyer of inoculant for soybean. Engaged in soybean contract growing scheme, this private company had included seed inoculation in their recommended package of technology before. When a contract grower got his supply of inputs from Nestle, it already included the inoculant. They really have to inoculate their seeds before they plant. Lately, however, the company ceased to include seed inoculation in their POT for two main reasons. One was that they observed that *Rhizobia* population was already high in some places and marginal benefit from continuous seed inoculation would be low. Another was that procuring the inoculant all the way from BIOTECH had become a tedious task to Nestle personnel.

The DA-RFU's provide a better venue for inoculant production and channel for distribution since they are scattered all throughout the country and they have field technicians who come in contact with farmers regularly. Despite this, only seven out of the fourteen DA-RFU's produce inoculants at limited capacities and worse still there were times when production had to stop either because of lack of personnel or electric power in the region. Other DA-RFU's do not produce inoculants at all simply because of lack of trained personnel.

As may be expected, given the existing setup and the constraints being faced, the volume of inoculant production in the country has been very low. The soybean and mungbean inoculant that were produced during the period 1990-94 had averaged to about 1.3 metric tons per year only (Table 2). This volume was just enough to cover about 57% and 2% of soybean and mungbean farm hectarage, respectively. (During the same period the average farm hectarages planted to soybean and mungbean were 3,301 hectares and 34,296 hectares, respectively.) The reason why the seed inoculation component was not evaluated in some of the concluded pilot production programs and technology commercialization is that most of the farmer-cooperators were not able to use the inoculant simply because they were not available when they were needed.

The annual average share of the Biotech's inoculant production to the total production was only 13% during the period 1982-84 but this increased to 45% during the last half of the 1980's and to 80% during the early 1990s. The share of

Biotech's inoculant production to the total market needs to be needs to be accounted vis-a--vis those of DA in the calculation of benefits since it appears that the point since we have to segregate the benefits derived from the use of inoculant produced at BIOTECH from the benefits derived from the use of inoculant produced at the DA because the inoculant technologies at the BIOTECH and DA were generated via independent researches in the respective units.

3. Evaluation of the Impact of Research

The procedure used in this study to evaluate the impact of research was the economic surplus approach of estimating returns to research. Here, relevant changes in consumer surplus and producer surplus based on the size of the vertical supply curve which was associated with the technology adoption. Three basic assumptions were made to simplify the calculations. These were the linearity of demand and supply curves, the parallel shift in supply curve due to technology adoption, and the closed economy assumption. The data used in the analysis were based on cost and returns estimates derived from both primary and secondary sources. Although regional estimates were attempted in this study, only the aggregate national estimated are reported in this paper. On the basis of the costs and benefits of research, estimates of net present value and internal rate of return were estimated.

Tables 2a and 2b show the comparative cost analysis of producing soybean and mungbean with and without inoculant. On the average, soybean yield increased by 23% (from 1.22 to 1.5 metric tons per hectare) and the corresponding cost reduction is about 12% (P1,478). For mungbean, yield increases by about 16% and the equivalent cost reduction is 5% (P657). The figures shows that both crops benefit from inoculation in terms yield increases which translate into unit cost reduction. Table 3 shows the preliminary figures on the pattern of investment costs and benefits for mungbean and soybean. It should be noted that year 1 goes as far back as 1974 during which the first funded studies leading to the development of inoculants started. On the other hand, ACIAR funding started in 1986. The basic data used to derive the figures on benefits for soybean and mungbean from the adoption of Rhizobium technology are shown in Tables 3a and 3b. These include production, consumption, prices, and the rate of technology adoption. The rate of technology adoption was computed based on the proportion of area using inoculated seeds.

In absolute terms the level of net benefits are not that large primarily because the total area planted nationally of field legumes compared to other crops is small. In relative terms, however, the estimates of net economic surpluses for each commodity appear to be increasing at a rapid rate. This is explained by the fact that in the mid-80s the adoption rate started at a very low level and during the latter years adoption rate is assumed to reach close to 85%. Given this pattern of net benefit, it may be concluded that Rhizobium research has a very high economic rate of return. The figures for soybean are higher than for mungbean. Based on the two crops alone, the net present value of the research on Rhizobium at UPLB over the period 1974 through 2003 is over P10 million with an internal rate of return is about 39%.

Contribution of ACIAR

In the previous section, it was shown that the research assistance of ACIAR is only part of the overall research effort toward the generation of a technology usable to farmers, namely the production of Rhizobium inoculants. In evaluating its economic benefits, we calculated the benefits of Rhizobium research in general and had shown that the overall research effort is socially profitable based on net present value and the internal rate of return..

One issue that comes up is in the case of multi-project research, how do we determine the benefits of the research attributable to a particular research funding agency such as ACIAR. This issue of benefit attribution is not new. When there are several components working together and interacting to achieve certain quantifiable objectives, it is often of interest to know how much of the incremental benefit or returns are attributable to a particular component. This seems similar to the evaluation of project benefits say from an integrated development project where there are several components like irrigation and credit and infrastructure, adaptive research and extension etc. and we attempt to determine how much of the total project benefits are attributable to irrigation.

In the case of research benefits, it is obvious that the benefits accruing to it due to technical change is a product of cumulative efforts starting perhaps with certain basic researches leading to the development of a technology. Having accounted for the all costs and benefits, we are able to arrive at estimates of the rate of returns of research. However, if we wish to single out the contribution of a particular research program as a component of a larger process involved in producing the technology, then some kind of procedure to apportion research benefits has to be done.

It appears that there are two obvious alternative criteria for apportioning total benefits in a multi-project research activity: (1) based on proportion of funding of an agency and (2) based on subjective rating of knowledgeable scientists of the proportion of contribution of a particular funding agency.

The first alternative, namely to apportion the total benefits according to the level of funding appears to be easier and more objective although our experience shows that it is not an easy task to re-construct the funding of prior related researches. One problem is that it may be argued that funding level does not necessarily translate into proportionate benefits. For example, a large amount of research funds can be spent and only have a marginal contribution towards the production of the technology. Another problem is trying to make the cost estimates comparable due to changes in purchasing power. In this case, there would be a need to convert nominal research costs to real research costs based on an appropriate deflator such as the consumer price index.

The second option, which seems to be a more practical approach, is to obtain from scientists a "ball park" figure of their informed and best estimate of the contribution of a particular research component to the production of a technology. Once we have the overall estimate of research benefit, then it is a simple matter of applying the estimated relative contribution of the effort. Hence, it would be possible to make a statement that the contribution of a specific research program funded by a particular agency is so much.

This issue of benefit attribution still needs to be looked further into in this preliminary study. To the extent that research cost and benefit estimates are already computer templates, it would be a simple exercise to undertake some simulation and "what-if" analyses with respect to effect of changing funding levels or subjective valuations of research contribution.

4. CONCLUSIONS

In this paper, we have attempted to present the results of an evaluation of a collaborative project between scientists in the Philippines and Australia which was supported by ACIAR. The project looked at a range of aspects of the use Rhizobium in food legume crops. The paper highlights the importance of developing a detailed background to the full research effort to ensure an effective evaluation. In particular it highlights the importance of ensuring the full research lag is taken into account and that the benefits from the research efforts are not attributed to just a sub-set of the research.

The paper has described the various research activities focusing on the nitrogen fixation of legumes by Rhizobium. It was shown that there was indeed a number of research projects funded by various agencies before the ACIAR projects which together helped to produce the Rhizobium inoculants for various types of legumes, particularly soybean and mungbean. These previous researches, which were mostly done during the period 1974-87 done mostly by UPLB researchers, laid the ground work for the ACIAR/UPLB collaborative researches on nitrogen fixation starting in 1988-90 and in 1990-91. As of today, there are still several on-going related researches with focus on production of legume inoculants, development of microbial inoculants for stress environments, commercialization of inoculants for small farmers, and utilization of rhizobium-mycorrhiza interaction under acid soils.

Although a large proportion of the inoculants were produced during and after the ACIAR project, it seems clear that a large proportion of the success of the project is due to the series of researches on nitrogen fixation. Clearly, the fact that a number of the researches started in the 70s and continued on through the 80s implies that attributing research benefits to the ACIAR projects would overstate the real returns to the ACIAR/UPLB collaborative research.

This suggests that if we are to determine the social benefit of ACIAR funded research or any research program in the continuum of researches, then there is a need to devise a procedure to apportion the total benefits in an effort to determine the benefits attributed to a particular research. There appear to be two alternative approaches of apportioning total benefits. The first is based on the level of funding and the second is to assign weights to the various researches according to the subjective evaluation of some 'arbiter' which should be an informed scientist who has observed or is knowledgeable of the entire research process.

Table 1. List of research projects on Rhizobium at the UPLB, their sources of funds, and duration

PROJECT TITLE	SOURCES OF FUNDS	'74	'75	'76	'77	'78	'79	'80	'81	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97
The Nitrogen Fixing Systems: The Rhizobium-Legume Symbiosis	UPLB-PCARRD	■	■	■	■																				
Nitrogen Fixation by the Rhizobium-Legume Symbiosis	UPLB-BIOTECH							■	■	■	■	■													
Legume Inoculation with Rhizobia: Field Trials	UPLB-PCARRD- NifTAL								■	■	■														
Nitrogen Fixation in Selected Rhizobium-Legume Associations	NSTA-UPLB										■	■	■												
Utilization of Microbial Associations in Peanut Production	UPLB-PCARRD-PCRSP										■	■	■	■	■										
Utilization of Rhizobium Technology in Food Legume Production	UPLB-BIOTECH												■	■	■	■	■								
Ecology of Rhizobium Nodulating Grain Legume in the Philippines	UPLB-PCARRD-ACIAR													■	■										
Biological Factors that Predict the Behavior of Bradyrhizobia in Tropical Soils	UPLB-PCARRD-Niftal														■	■	■								
Biological Nitrogen Fixation in Food Legume Production System	UPLB-ACIAR															■	■	■							
Pilot Plant Production of Rhizobial Inoculants	UPLB-BIOTECH																	■	■	■	■	■	■		
Pilot Testing of the Effectiveness of Rhizobium and VAM in Increasing Growth & Yield of Peanut, Mungbean, & Soybean	DA-NAFC																	■	■						
Nitrogen Fixation by Grain Legumess in Rice-Based Cropping System and Its Residual Effect	AIDAB/ACIAR																	■	■						
Biological Nitrogen Fixation Under Stress Environment	IAEA																				■	■	■		
Farmers' Utilization and Improvement of Legume Inoculants	DA-BAR																				■	■	■	■	
The Production, Quality Control, and Use of Legume Inoculants	UPLB-BSWM-ACIAR																					■	■	■	
Development of Microbial Inoculants for Stress Environments	PCASTRD																					■	■	■	
Lab to Land: Application and Commercialization of Legume Inoculant for Small-Scale Farmers	PCARRD-ATI																					■	■	■	■
Utilization of the Legume-Rhizobium-Mycorrhiza Interaction in Mungbean and Soybean Production Under Acid Soils	UPLB-PCARRD-DOST																							■	■

REFERENCE TO ACRONYMS:

ACIAR - Australian Center for International Agricultural Research

Table 2. Yearly production of inoculants for soybean and mungbean
(in kilograms)

YEAR	SOYBEAN			PEANUT			BOTH CROPS		
	BIOTECH	BSWM	Total	BIOTECH	BSWM	TOTAL	BIOTECH	BSWM	TOTAL
1982	3	111	114	3	82	85	6	193	199
1983	2	45	47	41	88	129	43	133	176
1984	31	111	141	2	160	162	32	271	303
1985	199	83	282	69	203	271	268	285	553
1986	66	106	172	47	183	231	113	289	402
1987	140	75	215	27	161	188	167	236	403
1988	139	114	253	95	140	235	234	254	489
1989	330	88	418	29	138	167	359	226	585
1990	521	53	573	82	177	260	603	230	833
1991	1,086	146	1,233	104	261	364	1,190	407	1,597
1992	1,588	18	1,606	45	182	227	1,633	200	1,833
1993	1,385	25	1,410	11	127	138	1,396	152	1,548
1994	604	44	648	49	181	230	653	225	877
Annual Averages									
1982-84	12	89	101	15	110	125	27	199	226
1985-89	175	93	268	53	165	218	228	258	486
1990-94	1,037	57	1,094	58	186	244	1,095	243	1,338

Sources: BIOTECH and BSWM

Table 2a. Comparative cost analysis of producing soybean with and without inoculant

ITEMS	UNIT	RATE	WITHOUT INOCULANT Quantity	WITHOUT INOCULANT Amount	WITH INOCULANT Quantity	WITH INOCULANT Amount
LABOR				5,316.83		5,622.50
Land preparation				1,240.00		1,240.00
Plowing	P/ha	500.00	2	1,000.00	2	1,000.00
Levelling	P/MAD	120.00	1	120.00	1	120.00
Furrowing	P/MAD	120.00	1	120.00	1	120.00
Planting	P/MD	70.00	3	210.00	3	210.00
Cultivation	P/MAD	120.00	2	240.00	2	240.00
Off-barring	P/MAD	120.00	2	240.00	2	240.00
Hand weeding	P/MD	70.00	7	490.00	7	490.00
Hilling-up	P/MAD	120.00	2	240.00	2	240.00
Fertilization	P/MD	70.00	2	140.00	2	140.00
Pest & disease control	P/MD	70.00	5	350.00	6	420.00
Harvesting				2,166.83		2,402.50
Cutting & Binding	P/ha	1000.00	1	1,000.00	1	1,000.00
Threshing	P/sack	40.00		813.33		1,000.00
Drying	P/MD	70.00	2	140.00	2	140.00
Sorting	P/sack	1.50		30.50		37.50
Hauling	P/kg	0.15		183.00		225.00
MATERIALS				3,658.50		3,792.50
Seeds	-P/kg	14.00	60	840.00	60	840.00
Inoculant	P/packet	20.00			6	120.00
Fertilizers				1,275.00		1,275.00
Complete	P/bag	350 00	2	700.00	2	700.00
Urea	P/bag	305.00	1	305.00	1	305.00
Potash	P/bag	270.00	1	270.00	1	270.00
Insecticide				1,257.50		1,257.50
Pennant	P/500 ml	162.50	1	162.50	1	162.50
Hostathion	P/500 ml	290.00	1	290.00	1	290.00
Decis	P/500 ml	215.00	1	215.00	1	215.00
Cymbush	P/500 ml	330.00	1	330.00	1	330.00
Larvin	P/250 ml	260.00	1	260.00	1	260.00
Fungicide	P/pack	90.00	2	180.00	2	180.00
Plastic twine	P/roll	45.00	1	45.00	1	45.00
Plastic bags				61.00		75.00
TOTAL VARIABLE COSTS				8,975.33		9,415.00
FIXED COSTS				6,640.26		7,567.85
Management				2,100.00		2,100.00
Land rental				3,965.00		4,875.00
Land tax				13.75		13.75
Interest on capital				359.01		376.60
Depreciation				202.50		202.50
Plow				75.00		75.00
Leveller				10.00		10.00
Furrower				60.00		60.00
Sprayer				50.00		50.00
Scythe (2)				7.50		7.50
TOTAL COST				15,615.60		16,982.85
TOTAL COST PER UNIT				12,799.67		11,321.90
UNIT COST REDUCTION						1,477.77
TOTAL REVENUE	P/MT	13000.00	1.22	15,860.00	1.5	19,500.00

Table 2b. Comparative cost analysis of producing mungbean with and without inoculant

ITEMS	UNIT	PRICE/UNIT	WITHOUT INOCULANT		WITH INOCULANT	
			Quantity	Amount	Quantity	Amount
LABOR				2,640.00		3,000.00
Land preparation				600.00		600.00
Plowing	P /MAD	120.00	3	360.00	3	360.00
Harrowing	P /MAD	120.00	1	120.00	1	120.00
Furrowing	P /MAD	120.00	1	120.00	1	120.00
Planting	P /MD	60.00	4	240.00	4	240.00
Hand weeding	P /MD	60.00	8	480.00	8	480.00
Cultivation	P /MAD	120.00	2	240.00	2	240.00
Pest & disease control	P /MD	60.00	4	240.00	4	240.00
Harvesting				840.00		1,200.00
Priming	P /MD	60.00	9	540.00	15	900.00
Threshing	P /MD	60.00	2	120.00	2	120.00
Hauling	P /MD	60.00	1	60.00	1	60.00
Drying	P /MD	60.00	2	120.00	2	120.00
MATERIALS				1,640.00		1,780.00
Seeds	P /kg	24.00	30	720.00	30	720.00
Inoculant	P /packet	20.00			4	80.00
Insecticide				550.00		550.00
Lannate	P /liter	300.00	0.75	225.00	0.75	225.00
Folidol	P /liter	250.00	0.75	187.50	0.75	187.50
Cymbush	P /liter	550.00	0.25	137.50	0.25	137.50
Food	P /head/day	10.00	37	370.00	43	430.00
TOTAL VARIABLE COST				4,280.00		4,780.00
FIXED COST (P/cropping)				4,795.69		5,173.66
Management				2,000.00		2,000.00
Land rental				2,285.16		2,640.63
Land tax				63.00		63.00
Interest on capital				171.20		191.20
Depreciation				276.33		278.83
Plow				66.67		66.67
Harrow				66.67		66.67
Sprayer				86.67		86.67
Bolo				16.00		16.00
Scythe				12.00		12.00
Hoe				20.00		20.00
Plastic bags				8.33		10.83
TOTAL COST				9,075.69		9,953.66
TOTAL COST PER UNIT				12,907.65		12,250.66
UNIT COST REDUCTION						656.99
TOTAL REVENUE	P /mt	16,000	0.70	9,140.63	0.81	10,562.50
% Change in yield						0.16
% Change in cost of production/unit						-0.05

Table 3. Cost and benefit analysis of research on rhizobium at the UPLB (in Philippine pesos (A$1 = P19))

YEAR	BENEFITS			COSTS			NET	PRESENT VALUES		
	Soybean	Mungbean	Total	ACIAR	non-ACIAR	Total	BENEFITS	Benefits	Costs	Net Benefits
1974					13,880	13,880	(13,880)	-	12,852	(12,852)
1975					27,760	27,760	(27,760)	-	23,800	(23,800)
1976					27,760	27,760	(27,760)	-	22,037	(22,037)
1977					13,880	13,880	(13,880)	-	10,202	(10,202)
1978								-	-	-
1979								-	-	-
1980					71,000	71,000	(71,000)	-	41,428	(41,428)
1981					47,249	47,249	(47,249)	-	25,527	(25,527)
1982	8,199	3,773	11,972		152,578	152,578	(140,606)	5,989	76,327	(70,338)
1983	4,036	49,834	53,870		298,949	298,949	(245,079)	24,952	138,471	(113,519)
1984	98,400	2,070	100,470		358,423	358,423	(257,952)	43,090	153,721	(110,631)
1985	686,383	81,796	768,179		301,054	301,054	467,125	305,054	119,553	185,502
1986	236,396	64,317	300,713	40,950	534,542	575,492	(274,778)	110,572	211,607	(101,035)
1987	509,092	35,008	544,100	150,076	421,600	571,676	(27,577)	185,245	194,633	(9,389)
1988	501,563	126,171	627,734	311,744	635,334	947,078	(319,344)	197,888	298,558	(100,671)
1989	1,627,383	42,528	1,669,912	315,143	624,128	939,271	730,641	487,431	274,164	213,267
1990	2,387,474	118,062	2,505,535	147,840	967,169	1,115,009	1,390,526	677,168	301,352	375,816
1991	4,494,683	146,340	4,641,022		597,359	597,359	4,043,663	1,161,411	149,488	1,011,923
1992	7,152,125	64,235	7,216,360		567,253	567,253	6,649,107	1,672,118	131,439	1,540,678
1993	6,707,512	15,020	6,722,532		162,540	162,540	6,559,992	1,442,307	34,873	1,407,435
1994	2,909,690	71,348	2,981,039	997,243	614,194	1,611,437	1,369,601	592,200	320,121	272,079
1995	2,819,360	69,440	2,888,800	153,7[illegible]	807,586	961,348	1,927,452	531,367	176,831	354,536
1996	3,176,849	72,660	3,249,508	180,264			3,249,508	553,441	-	553,441
1997	3,621,197	77,320	3,698,518				3,698,518	583,254	-	583,254
1998	4,239,310	79,309	4,318,619				4,318,619	630,596	-	630,596
1999	4,987,337	82,898	5,070,235				5,070,235	685,505	-	685,505
2000	5,803,413	86,614	5,890,027				5,890,027	737,354	-	737,354
2001	6,715,697	89,949	6,805,646				6,805,646	788,868	-	788,868
2002	7,731,857	93,803	7,825,659				7,825,659	839,909	-	839,909
2003	7,729,217	97,748	7,826,965				7,826,965	777,823	-	777,823
Total	74,147,174	1,570,241	75,717,414	2,297,022	7,244,238	9,360,996	66,356,418	13,033,541	2,716,986	10,316,555

Net Present Value	12,044,694
Internal Rate of Return	39%
Discount Rate	0.08
IRR Guess	0.5

Table 3a. Basic data used in the calculation of benefits derived from the adoption of rhizobium technology for soybeans

YEAR	PRODUCTION (mt)	CONSUMPTION (mt)	PRICES (P/mt)	RATE OF TECH ADOPN	BENEFITS		
					Producer	Consumer	Total
1982	8,955	267,732	4,974	0.0004	5,364	2,835	8,199
1983	7,449	207,981	5,108	0.0002	2,641	1,396	4,036
1984	6,732	234,432	6,812	0.0066	64,380	34,021	98,400
1985	7,896	168,378	7,766	0.0394	449,236	237,147	686,383
1986	6,553	234,803	7,705	0.0162	154,681	81,715	236,396
1987	6,735	46,270	8,269	0.0360	333,159	175,932	509,092
1988	5,936	344,775	8,647	0.0377	328,257	173,306	501,563
1989	4,567	362,959	8,351	0.1583	1,066,508	560,875	1,627,383
1990	4,946	405,902	7,640	0.2140	1,565,937	821,536	2,387,474
1991	3,257	397,136	9,903	0.6070	2,957,091	1,537,592	4,494,683
1992	3,687	467,231	9,475	0.8488	4,717,496	2,434,629	7,152,125
1993	4,054	563,015	10,408	0.7262	4,416,368	2,291,144	6,707,512
1994	4,057	536,931	11,830	0.3173	1,908,283	1,001,407	2,909,690
1995	3,932	522,392	12,796	0.3173	1,848,696	970,664	2,819,360
1996	4,014	540,779	12,796	0.3500	2,083,599	1,093,249	3,176,849
1997	4,001	533,367	12,796	0.4000	2,375,890	1,245,308	3,621,197
1998	3,983	532,180	12,796	0.4700	2,782,838	1,456,472	4,239,310
1999	3,999	535,442	12,796	0.5500	3,275,750	1,711,587	4,987,337
2000	3,994	533,663	12,796	0.6400	3,814,214	1,989,199	5,803,413
2001	3,992	533,762	12,796	0.7400	4,416,949	2,298,749	6,715,697
2002	3,995	534,289	12,796	0.8500	5,089,257	2,642,600	7,731,857
2003	3,994	533,904	12,796	0.8500	5,087,520	2,641,698	7,729,217

Source: Bureau of Agricultural Statistics

Supply Elasticity	0.37
Demand Elasticity	0.70

Table 3b. Basic data used in the calculation of benefits derived from the adoption of rhizobium technology for mungbean

YEAR	PRODUCTION (mt)	CONSUMPTION (mt)	PRICES (P/mt)	ADOPTION RATE	BENEFITS Producer	Consumer	Total
1982	26,190	26,289	5,158	0.0002	2,177	1,596	3,773
1983	24,857	24,888	5,792	0.0030	28,750	21,083	49,834
1984	25,086	25,070	9,932	0.0001	1,194	876	2,070
1985	25,287	26,569	11,750	0.0048	47,190	34,606	81,796
1986	25,919	37,397	11,785	0.0033	37,106	27,211	64,317
1987	25,266	32,283	11,075	0.0019	20,197	14,811	35,008
1988	26,573	35,211	11,543	0.0065	72,791	53,379	126,171
1989	25,134	48,321	13,783	0.0021	24,536	17,993	42,528
1990	26,649	43,937	14,567	0.0056	68,113	49,949	118,062
1991	25,099	38,383	15,625	0.0076	84,428	61,912	146,340
1992	23,213	40,926	16,387	0.0034	37,059	27,176	64,235
1993	23,421	33,298	17,486	0.0009	8,665	6,355	15,020
1994	24,218	49,111	18,773	0.0035	41,163	30,185	71,348
1995	23,617	41,111	21,149	0.0037	40,062	29,378	69,440
1996	23,752	41,173	23,825	0.0038	41,919	30,740	72,660
1997	23,862	43,799	26,841	0.0040	44,608	32,712	77,320
1998	23,744	42,028	30,237	0.0041	45,756	33,554	79,309
1999	23,786	42,333	34,064	0.0043	47,826	35,072	82,898
2000	23,797	42,720	38,375	0.0045	49,970	36,644	86,614
2001	23,776	42,360	43,231	0.0047	51,894	38,055	89,949
2002	23,786	42,471	48,702	0.0049	54,117	39,686	93,803
2003	23,786	42,517	54,865	0.0051	56,393	41,355	97,748

Source: Bureau of Agricultural Statistics

Supply Elasticity	0.66	820,500
Demand Elasticity	0.9	