BIOTECHNOLOGY AND COMMUNITY DEVELOPMENT FOR FOOD PRODUCTION

A CASE STUDY

RHIZOBIUM INNOCULANT PRODUCTION IN THAILAND, APPLIED TO TROPICAL SOYBEAN PRODUCTION FOR FOOD.

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Biotechnology and community development for food production: a case study in Thailand on *Rhizobium* inoculant production applied to tropical soybean production for food.

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Abstract

The production of *Rhizobium* inoculant technology on a small scale for direct use by small scale farmers marks one of the first uses of cutting-edge biotechnology to reach the rural poor. Indeed, although the technology is proven to our satisfaction, research in attaining greater cost effectiveness for process, raw materials, and methods of application is continuing even now. The technology transfer process is a collaborative effort between AT International and the SVITA Foundation. The researchers at the NifTAL Project pursued avenues which led to praccical, cost effective, and scale-neutral technology for the production of *Rhizobium* inoculant. The ability of AT International to recognize promising technologies combined with the apt research of the NifTAL Project and the competent management of the SVITA Foundation make for a successful project. AT International implements its mission with public funds made available by the U. S. Congress through the Agency for International Development in cooperation with the Employment and Small Enterprise Division of the Office of Rural and Institutional Development which is part of the Bureau of Science and Technology.

In order to understand the financial and administrative aspects of this project, it will be useful to sketch for you what kind of organization AT International is. We will also review the technology which is at the heart of the project and we will estimate the commercial capacity of the product in the economy of the Thai farmer.

A private, not-for-profit corporation formed by the Congress of the US in 1978, AT International is currently funded by the U.S. Agency for International Development with the mission of applying appropriate technologies to the problems of rural development in less-developed countries. Appropriate technologies are of a scale which will make the most positive contribution to the economy of the client community. That is to say, appropriate technology, properly understood and applied can contribute significantly to national economic growth. The priority technical areas of AT

International are agricultural products processing and use of agricultural wastes, local mineral resource technologies, and equipment and support for small farms. It is this latter to which *Rhizobium* inoculant production belongs. When selecting from among alternative candidate projects and the technologies they represent, AT International chooses projects which contain an innovative element. We seek in this way to stimulate the pursuit of technical innovation among our clients and to encourage imaginative approaches to rural development which can directly and expeditiously aid the rural poor. Indeed, some appropriate technology practitioners have come forward with ideas for projects taken from the vanguard of biotechnology developments of just the past few years. In this area, projects have included fermentation procedures for food and feed, plant tissue culture, and various kinds of aquaculture in addition to small scale *Rhizobium* inoculant production. Not only should a project contain an innovative element, but the project should result in a sustaining commercial enterprise, one which will continue to function and bring benefits to its owners long after the founding funds have been absorbed.

In addition to the in-country partners who come forward with ideas for development into projects, AT International has begun to call more and more upon the research centers of the Consultative Group for International Agricultural Research (CGIAR), specifically, Centro Investigacion Agriculture Tropical (CIAT), Centro Internacional de la Papa (CIP), and International Rice Research Institute (IRRI), (and Asian Vegetable Research and Development Center (AVRDC) of Taiwan, an affiliate member) for technologies which may be proven and ready for dissemination. AT International also provides technical assistance, and capital in the form of grants and loans to partner organizations. AT International also draws freely on publication of works funded by USAID and maintains contact with our European colleagues in development, e.g. Gesellshaft fuer Technische Zusammenarbeit (GTZ), Schweizerische Kontaktstelle fuer Angelpasste Technik (SKAT), Groupe de Recherche et d'Echanges Technologiques (GRET), Stichting Technische Ontwikkeling Ontwikkelingslanden (TOOL) and International Development Research Centre (IDRC) in Canada.

AT International also works to disseminate appropriate technologies through support of APPROTECH Asia, a consortium of appropriate technology practitioners such as Yasayan Dian Desa (YDD) ("The Light of the Village") in Indonesia, and the Philippine Businesses for Social Progress (PBSP). In addition, sister organizations of AT International, such as Intermediate Technology Development Group (ITDG) of the UK, Appropriate Technology Development Association (ATDA) of India and Appropriate Technology Group (ATG) of Sri Lanka also regularly exchange information and provide support to requestors. This is the kind of institution AT International is, and its institutional setting.

The technology is based upon a marvelous relationship between certain plants and a group of certain bacteria. The leguminous higher plants are able to form a symbiotic relationship with *Rhizobium* bacteria and through a yet not understood process, the bacteria are able to gather, solublize and make available to the plant all or part of the nitrogen requirement for synthesis of amino acids and proteins. This symbiosis requires sharing with the bacteria part of the carbohydrate the plant generates through the photosynthetic process. The mechanism of the formation of symbiosis, nodulation, occurs when the bacteria invade the growing roots of the plant. Some plants nodulate only with certain varieties of *Rhizobia*, while others may form effective nitrogen fixing symbiosis only with a few of the strains which can nodulate them. Indeed, competition can occur between strains which can nodulate (and absorb carbohydrate nutrients) but not fix nitrogen, and those which can do both. For this reason, inoculation with appropriate strains is practiced in order to ensure nodulation *and* nitrogen fixation in economically valuable species of grains and forage plants (NAS 1979). This biologically benign and ecologically sound approach to increasing food production needs no further development here.

Large scale production of *Rhizobium* inoculant has been practical for many years. It includes strict quality control, fermentation to increase populations, inoculation onto peat, packaging, storage and distribution. Mannitol (a poly alcohol) and yeast extract in a basal nutrient medium is the standard formulation for culture of rhizobia species (Vincent 1970). Oxygen is supplied by special means in vessels of 1000 to 2000 liters each (Burton, 1967). Large fermentors, which must also be pressure vessels to allow steam sterilization, are expensive of purchase, operation and maintenance, and require a skilled staff of operators. Because of the seasonal nature and finite shelf life of the inoculant, production tends to be discontinuous, which can be a penalty to the amortization of high-cost capital equipment. Discontinuous production also poses problems of management of trained technical staff, requiring a delicate balance between a wage providing gainful employment (and thus staff loyalty) and managements need for a low labor rate. Large pressure vessels or the technology to fabricate them often are not available in the client country. From the point of view of AT International, which is committed to employing in-country resources, these are major disincentives for establishing the large scale enterprise. (Appropriate Technology International 1985). Storage and distribution of the inoculant in tropical countries can pose special problems because of loss of viability at high temperature. However, the work of Somasegaran, et al. 1984 suggests that most of the species studied remain viable after exposure to surprisingly high temperatures. Other workers (Zurkowski and Lorkiewicz 1978) demonstrated a loss of infectivity in *R. trifolii*. Clearly, since high temperatures may cause loss of viability and ability to fix nitrogen, depending on the strains and conditions of exposure, some countries may have to take special precautions to avoid loss of inoculant quality during distribution.

Taken together, the large capital investment, possible need for imported equipment, need for skilled staff, possible seasonality of operations and uncertainty of market size form formidable barriers to private entrepreneurs seeking a new business opportunity. Nevertheless, because ATI is a risk taking organization, ways were sought to bring the substantial benefits of biological nitrogen fixation to the small farmers of Thailand.

Technology Choice Considerations

Let us trace the course of events which led to a successful *Rhizobium* inoculant project.

In 1968 Roughley reported that three species of *Rhizobium* were able to reach maximum (ceiling) populations after three weeks when inoculated into peat, even though cultures of different ages (and therefore different populations) were used. Somasegaran and Halliday in 1982, carried out an experiment to test whether this attribute of these *Rhizobia* could be employed as a means of increasing the output of shaker-flask inoculant plants. Their experiment tested whether peat which was inoculated by deliberately diluted *Rhizobium* inoculant could reach and sustain acceptable numbers of the viable nitrogen symbiont. Results showed that for both the slow and fast growing strains tested a population of a hundred billion could be attained from a million to a hundred million per milliliter of inoculant. This represents one hundred to ten thousand fold increase. After six months, one hundred million bacteria per milliliter still persisted, and this is close to the acceptable standard for viable cells in moist peat (Date and Roughley 1977).

The potential for developing a small scale, small capital investment process was appreciated by a number of Thai scientists, led by Dr. Malee Suwana-adth. Dr Malee in 1983 was appointed to a government of Thailand committee for studying the means to disseminate interest in *Rhizobium* inoculant in Thailand.

The information announcing the successful work of Somesagaran was transmitted through the MIRCEN and the NifTAL (Nitrogen fixation in Tropical Agricultural Legumes) Project in Bangkok. It is a Thai government objective to achieve self sufficiency in soybean production and a program of high-yield seed multiplication, research, and extension over ten years has shown results with a 1983-1984 crop year production increase of about 20% (A. Pookpakdi, 1985). The AT International project is intended to aid small farmers to increase production at very small cost thereby increasing incomes and tending to reverse the trend towards tenancy. Thai government National Statistics Office 1983 data show that the percentage of the tenant farmers tending downward from 1937 to 1963, then rising again. The hypothesis is that a shift from extensive to intensive agriculture is occurring as less virgin land is available for tillage. This has led to losses of farms as greater indebtedness occurs due to the need to purchase chemical fertilizers to support cash-crop intensive agriculture. The government has instituted policies to assist the farmer including training, incentives to diversify crop varieties (for example away from cassava and towards soy beans) and encouragement of foreign investments in the agricultural sector.

Illustrative of the GOT commitment to developing self sufficiency in soybean production is the construction of a large fermentation plant operated by the Department of Agriculture of Thailand at Bangkhen. This plant with complete research and quality control facilities will supply Rhizobium inoculant to large scale farmers. The AT International sponsored project will supply the smaller farmers, the farming cooperatives, and those in hard to reach areas of Thailand.

The technology which forms one cornerstone supporting this project (the other three being the competent support and administration of our Thai partners, the market for the inoculant which comes from the robust common sense of the Thai farmer, and the capital provided by AT International is a direct adaptation of the work of Somasegaran at NifTAL.

Since the rhizobia have been demonstrated to be able to increase their population by at least one log on sterile peat and no other nutrients except the small amount of diluted medium which passes during the inoculation of the pouches, the success of technology transfer depends upon the following:

1. proper instruction in preserving sterile technique.

2. documented quality control procedures including culture medium formulation from approved materials, correct quantitative formula; use of correct germ plasm; effectiveness testing.

3. appropriate monitoring of the process to assure that sufficient populations exist in the inoculant.

4. attention to and control, where possible, of the environmental conditions surrounding transport and distribution.

5. inventory control to assure fresh, effective stocks.

The process of small scale inoculant production, as we are developing the commercial process, resembles very much a laboratory process. It begins with inoculation on standard liquid media of the appropriate Rhizobium strains and shake-culture of 500 to 1000 ml to a population level of 10 to the ninth power of cells per milliliter. Standard laboratory pyrex flasks are used. The culture is then diluted 50 to 1000 times in a large flask at the appropriate rate. The diluted inoculant is then injected into sealed pouches containing sterilized peat. Some heat of hydration is liberated following injection of the inoculant and this is dissipated during a manual or mechanical kneading of the pouch to distribute the moisture more evenly. This dilution technique, then, using very inexpensive equipment and supplies, produces a sufficient number of pouches of inoculant from one liter of culture to inoculate 112.5 hectares of soybeans. At least a theoretical increase of 20%, as seen in field trials in Thailand would result in 250 kg of soybeans increased production from one liter of inoculant. In addition to the usual furniture and equipment for handling, filling and sealing pouches, little other than autoclaves, and weighing and mixing equipment is needed. Charcoal or fossil fuel fired autoclaves have been designed and tested, and could be constructed in Thailand.

The technology is tested and acceptable today. Certain areas of improved economic efficiency and cost reduction are under investigation at this time. These include tests which examine the feasibility of substitution locally available sucrose (cane sugar) by the microsymbiant, Rhizobium. Recently published work (Somasegaran, 1985) tested peat samples of diverse origin for compatibility with diluted liquid cultures. Significant survival differences were seen related to the peat and this fact will lead us to test the peat which occurs in Southern Thailand as a possible candidate for substitution of the imported sedge peats used as the medium for inoculation. Composted bagasse and possibly other agricultural by-products could be substituted for imported peat. These points obviously go to the issue of substituting locally available resources for imported raw materials, which would be the preferred strategy for adding value to local raw materials.

Since Rhizobium inoculant cannot stand alone as a desired commodity, it is necessary to promote the use of the inoculant and to make available seeds which are responsive to the inoculant by showing significantly higher yields.

In Thailand, on soils similar to those used by local farmers, increased yields of 50% have been seen in test plots. In field trials, farmers have experienced 10-20% increases of yield for very modest inputs (B20), 87 cents per pouch which treats 5kg of beans or 1/9th hectare), but a further cash savings results because up to a 60% reduction of inputs of nitrogenous fertilizer is possible simultaneously.

(Pookpakdi, op. cit.)

If the technology package meets the performance criteria as expected, the major costs of a small scale production unit will be eliminated; namely, expensive imported equipment, inventories requiring cold storage, imported raw materials and associated transportation costs and production delays, energy inputs, and size of loss through contamination.

Economic Appraisal

Obviously, a realistic economic appraisal of a small scale unit awaits the results of its technical feasibility; however, a preliminary analysis was carried out using cost assumptions that could be reasonably expected to occur. This analysis indicates that the minimum economic size for a small scale unit will have a plant capacity of 8 tons per year. The capital required to set up a plant with this capacity would be B748,875 (or US $32,500). The unit cost per 500 gram package, the unit of sale, is B16.63 (US 72 cents). The break-even percentage for the unit would be 70% assuming favorable financing terms. The annual profitability is B159,600 (US $7,000) assuming the normal tax waiver is extended due to the nature of the enterprise. The internal rate of return on capital invested would be 12.3%. This analysis supports two conclusions:

- o that a small scale unit with a capacity of 8 tons/year can operate on a self-sustaining basis with moderate risk and gain;
- o that at this scale, it does not appear to be an attractive investment for an investor looking for a good return on capital.

The initial target group for ownership of a small scale unit is a farmers group whose principal interest would be access to a needed, low cost production input, rather than return on capital. Assuming a conservative estimate of productivity increases which can result from the use of *Rhizobium* inoculant (20%), the annual incremental income benefit to all members of a farmers association (assume 400 members) would be B800,000 (US $34,783) approximately 5 times the annual profitability of the unit. The annual incremental income benefit to 1,600 small growers, which constitutes the market size of an 8 ton/year plant, would be B3,200,000 (US $139,130) or approximately 20 times the annual profitability of the unit. Therefore, the overall income benefit from the use of *Rhizobium* significantly adds to the economic soundness of a small scale production unit.

The project will take steps to improve the commercial attractiveness of the unit. Since *Rhizobium* will be produced only six months during the year, studies will be carried out to identify alternative products that could be produced using the same equipment. Market trials will be conducted on the use of rhizobium for other legumes, such as mung beans and peanuts also grown in Thailand.

The principal hypothesis this project will test is that a small scale enterprise can manufacture Rhizobium inoculant on a self-sustaining basis, and meet the needs of small farmers with an effective and low cost product. It is assumed that project planning has accounted for and is designed to deal with the major risk factors which could disable the success of the project, namely:

- that a technology package cannot be developed to specifications;
- that the standards of product quality (cell count and nitrogen fixing efficiency) cannot be met;
- that non-technical persons cannot adequately manage the production unit to meet quality control standards;
- that the market development effort will fail to convince soybean growers that Rhizobium inoculated soybean seeds are the preferred inputs for soybean cultivation;
- that, if farmers are convinced, sources of agricultural credit will fail to meet credit demands of farmers participating in the project.

However, if a small scale production unit can pass the technical and commercial tests designed into this project, its comparative advantages in disseminating Rhizobium technology are that:

- Investment is scaled to a size that farmers groups can own;
- Increased and timely access of this production input to small farmers is assured;
- A high quality product can be delivered at a lower unit cost of production;
- A source of technical assistance on the use of rhizobium is closer to the end user.

Project Design

ATI provided financial support amounting to B 3,121,000 (US $135,000 at an exchange rate of B 23 = US $1.00) to the SVITA Foundation to coordinate and manage a project to test the technical and economic feasibility of decentralized small scale systems of production and distribution of *Rhizobium* inoculant to small scale soybean growers. This applied research and development project is designed for a 32 month period (April 1984 to December 1986) to enable SVITA to carry out all stages of the development process including market development, adaptation and testing of the technology, commercial operation of one small scale production facility and final evaluation of its technical and commercial performance. The stages are:

1. Market Development (April - December, 1985)

SVITA will plan and coordinate a demonstration on the use and benefits of *Rhizobium* in the Chiangmai District, the site for this project. Working directly with farmers groups, SVITA will mobilize 1050 soybean growers in coordinating on-farm trials on both multiplying high yielding soybean seeds and soybean production organized as follows:

- Demonstration of Soybean Seed Multiplication: Five groups of ten farmers each will be trained and provided production inputs on credit (seeds, pesticides, *Rhizobium* inoculant) to grow high yielding soy bean seeds on 50 rai (ca 20 acres; 8 Ha.) of their own land. This demonstration was carried out in May and June prior to the growing season (July - October, 1984) so that the seeds were available for use by the soybean production groups. In subsequent growing seasons, the soybean seed groups will continue on-farm seed multiplication at increased levels with production credit partially supplied by the project and augmented by other credit sources.

- Demonstration of Soybean Production: One thousand farmers divided into 100 groups consisting of 10 members each, trained and provided production inputs on credit (high yielding seeds and rhizobium) to cultivate 1 rai per farmer (0.4 acre; 0.16 Ha) of inoculated soybeans. This production demonstration was conducted in July - October, 1984. Cultivation of rhizobium inoculated, soybeans will continue in subsequent seasons to a target of 16,000 rai by increasing the number of participating farmers to 1600 cultivating an average of ten rai (4 acres; 1.6 Ha).

At this stage, SVITA will carry out or contract for a market study to identify more favorable marketing channels for the sale of the soybeans, and to identify credit institutions willing to meet short term farmer production credit needs beyond the demonstration.

2. Technology Adaptation/Testing Stage (April 1984 - March 1985)

SVITA organized a working group consisting of specialists in microbiology and fermentation engineering to implement this stage of the project according to the following sequence of activities:

- o <u>Soil Analysis / Product Formulation</u>: One hundred soil samples from each of the sites of soybean production were to be analyzed to determine the most effective strains of <u>Rhizobium</u> in the project area. The proper combination or mixture of strains will be identified and tested in the laboratory.

- o <u>Testing Substitutes for the Growth Medium and Carrier</u>: Laboratory tests were to be conducted to confirm and/or reject the hypothesis that sugar cane juice is an acceptable alternative to imported mannitol for the growth medium and that sugar cane filter cake and/or municipal compost are acceptable alternatives to peat (available only in southern Thailand) for the carrier.

- o <u>Equipment Design</u>: Engineering designs for the fermentor and costs estimates on all equipment (to be fabricated or purchased) required for a small scale production facility will be prepared.

- o <u>Local Fabrication of Equipment</u>: SVITA will engage a local contractor to fabricate the necessary equipment.

- o <u>Commissioning of Pilot Plant</u>: The pilot plant will be commissioned at a site near Bangkok (probably at the Kamphaengsaen Campus of the Kasetart University) where it will be tested for its technical feasibility.

- o <u>Diversification</u>: Studies on product diversification will be carried out to identify alternative products that can be manufactured using the same equipment.

Assuming the pilot plant is certified for commercial use, a second plant will be commissioned using the same equipment at the site to be determined near Chiang Mai. A joint venture will be set up between a farmers group and SVITA to operate the plant. A technician, hired by SVITA at the outset of the project will be the manager of the plant. Funds are provided in the grant for SVITA to capitalize its 85% share of the plant; the farmers group will be expected to provide 15% of the capital required for the plant. A shareholders agreement will be executed between SVITA and the farmers group which will address, at a minimum, issues regarding management and control, ownership of shares, distribution of profits and buy-out provisions.

During this stage of the project, options for the distribution and sales of *Rhizobium* and high yielding soybean seeds will be studied. Among the options considered will be direct sales from the production facility and an intermediary sales depot/seeds service enterprise operated by a farmers group. This second option would combine several service lines: sale to farmers of *Rhizobium* and high yielding soybean seeds multiplied by the farmers in the project; and threshing, storage, and marketing of soybeans. The project budget contains credit funds to help capitalize the enterprise option that is chosen for support. SVITA will manage a capital fund budgeted for this project because neither development of commercial sources of credit could be tapped to finance the critical components of this project in the amounts and at the time required. The capital fund is earmarked for the following purposes: to finance short term production credit offered for 6 months at 12% per annum interest to the individual farmers who participate in the demonstrations on soybean multiplication and soybean production using *Rhizobium* inoculant; to finance SVITA's equity participation in the commercialization of the small scale rhizobium plant; to provide long term credit offered for 5 years at an interest rate of 16% per annum to finance the introduction of new product lines in the *Rhizobium* plant; and to finance the fixed assets and/or working capital needs of the sales/seed service enterprise. All reflows into the capital fund from loan repayments and dividends from SVITA's shareholding interest in the *Rhizobium* plant will be earmarked to help finance additional *Rhizobium* plants.

In addition to ongoing project monitoring, SVITA will organize and conduct two in-depth evaluation exercises: the first will coincide with the testing of the pilot plant to determine its technical feasibility, the second, conducted at the end of the project, to determine the commercial feasibility and replication potential of this small scale enterprise approach to *Rhizobium* production and distribution.

Anticipated Outputs

It is expected that the outputs at each stage of this project will be:

Market Development

- o Reliable data on market response to the use of *Rhizobium* inoculant are collected and analyzed with respect to farmers attitudes, proper handling and use, preference compared to chemical nitrogen fertilizers, and willingness and ability to pay for the input;
- o Marketing channels more favorable to the small scale soybean grower are identified;

- Source of quality high yielding varieties of soybean seeds is available at the project site;

- Sources of production credit are identified for expanded soybean seed and soybean production.

Technology Adaptation and Testing:

- Demonstration of the technical feasibility of a small scale *Rhizobium* production facility is completed and supported by performance data regarding product quality and costs;

- Alternative products are tested and a determination made of their suitability as additional products produced by the small scale unit.

Commercial Small Scale Production and Distribution Systems:

- Demonstration of the commercial feasibility of a production facility with a capacity of 8 tons/year is completed and supported by data regarding production costs, product quality, sales, and profit and loss statements;

- Demonstration of a cost efficient, reliable distribution/sales system is completed and supported by data on the operation of a sales/seeds service enterprise.

The effects of this project can be divided into medium and long term benefits.

Medium Term

- Income Increases: Incremental increases in income to 1600 soybean growers will occur, estimated at B 200/rai or at B 2000/year assuming an average of 10 rais/farmer in soybean cultivation;

- Productivity Increases: Productivity increases for soybean will occur, estimated at 20-50% per rai or an increase from current average yields of 150 kg/rai to 180 - 225 kgs/rai depending on soil types and other environmental factors;

- Nitrogen Enrichment of Soil: Increased amounts of usable nitrogen will be fixed in the soil of the farmers participating in the project;

- Technology Control: Control of a critical farm input will be exercised by small farmers as indicated by the commercial success of the *Rhizobium* production facility;

- o <u>National Strategy for Rhizobium Dissemination</u>: Rate of adoption of rhizobium will be accelerated by adding decentralized production and distribution systems as indicated by the sales of the commercial unit.

<u>Long Term</u>:

- o <u>Import Substitution</u>: Lower costs of adding nitrogen in the soil using rhizobium compared with chemical fertilizer as indicated by a reduction in imported nitrogen fertilizers. Increased local production of soybeans will reduce Thailand's dependence on soybean imports;

- o <u>Employment</u>: The viability of small farms will be increased by adopting soybean production as a meaningful economic enhancement to family incomes.

Evaluation

SVITA will be responsible for organizing two field evaluations during the course of the project. The first evaluation, timed to coincide with the test of the pilot rhizobium plant, will determine whether or not the technology package can be certified for commercial use. This determination will be based on three critical variables:

(1) Product quality as indicated by a minimum of one billion cell count per ml of inoculum and its nitrogen fixing efficiency;

(2) Technical performance of the equipment as indicated by negligible losses due to contamination; process controls managed within acceptable limits with respect to temperature, pH, agitation, solute concentrates, and time; operation efficiency by non-technical persons.

(3) Capital required and operation costs of pilot plant are within acceptable limits as indicated by the following benchmarks: B 200,000 for equipment costs, raw materials 30%, and energy costs between 6-9% of total production costs.

The second and final evaluation, which will be conducted at the completion of the project, will be divided into two areas of enquiry: a determination of the commercial feasibility of the small scale rhizobium plant and related sales and service enterprise; and the direct economic and social benefits arising from the dissemination of rhizobium inoculant. The indicators established to guide this evaluation include:

1. Commercial Feasibility:

- o sales reach 90% of plant capacity or 3.6 tons of rhizobium per season;
- o unit costs do not exceed B 34/kg;
- o loss factor, through contamination, does not exceed 3.5% of total production;
- o loan repayment on schedule;
- o distribution time of rhizobium from plant to end user does not exceed two days.

2. Economic and Social Benefits:

- o incremental income increases to soybean growers reach a minimum of B 2000/year;
- o productivity increases reach a minimum of 20%;
- o control of this technology is valued by soybean growers as indicated by their direct investment in the production facility;
- o replication potential of decentralized production and distribution systems of rhizobium as indicated by readiness of public and/or private financial institutions to invest in additional units.

SVITA will insure that the data required for these evaluations will be collected and easily retrieved when needed.

The structure of the spending plan was negotiated directly with the project partners and addressed technical needs first then the commercial aspects of sustaining enterprise.

The SVITA Foundation, ATI's project partner, is a private, not for profit, group of concerned business, academic, and technology professionals which organized in 1978. Their objective is to integrate and coordinate the efforts of NGO's in support of development programs which increase incomes and create jobs in rural areas and urban slums. SVITA had identified problems plaguing NGO efforts in Thailand as:

- o insularism and attempting to address development problems piecemeal.
- o failure to maximize each others resources and

experience by cooperating.

- o tendency to perceive development problems from the view point of their particular strength.

- o failure to take full advantage of government and private sector programs which could complement their own.

- o failure to take fuller advantage of in-country science and technology resources.

SVITA identifies resources and programs within the government, non-government, and business sectors and matches them with the development needs of the rural and urban poor, especially in regards to enterprise promotion activities, community organization, training, and technical backup. SVITA defines the critical points of inter-organizational coordination, agency responsibilities, and funding possibilities. In this way, it hopes to increase NGO ability to implement economic development projects that take advantage of sound financial, managerial, and technical resources and to improve government projects by using the unique skills of NGO's in working closely with beneficiaries in the field.

Since 1978, SVITA has established a reputation for facilitating the implementation of sophisticated economic development projects and for providing valuable services to its constituents. Its credits include:

- o Implementation of ATI grant to establish small enterprises. So far, this project has successfully coordinated the efforts of five agencies in establishing two village scale dairies.

- o Technical and commercial feasibility analysis of 30 small scale industries including soybean curd production, soybean threshing, fresh water fish processing, improved rice milling, animal feed production, rural energy production, and fuel alcohol distillation.

- o Drafting of major portions of the National Economic and Social Development Board's 5th and 6th Five Year Plan for (1) Science and Technology for Rural Development and (2) Women in Development.

- o Creation of APPROTECH Thailand, an association of Thai appropriate technology groups. The association has improved the transfer of technology between rural development agencies. It is an affiliate member of APPROTECH Asia.

- o Sponsorship of several dozen practical seminars on development issues;

- Brokering of $100,000 from local sources in support of rural industries, and has agreement in principle for an additional $250,000 to support the efforts of other NGOs;
- Publishing 35 titles ranging from the SVITA "Magazine for Children" to technical manuals on hog raising and crop production.

SVITA is the best qualified group to coordinate the activities of the proposed project because of its excellent relationship with the various parties contributing to the project, its operating flexibility, its proven management capacity, and its staff's intimate knowledge of the technology to be employed. Dr. Malee Suwana-adth is Executive Director.

The following three schedules comprise the budget breakdown:

A. Summary of Line Item Budget

1.	Market Development	
1.1.	Farmers Group Training	B 56,000[a]
1.2.	NGO Staff Support Costs	B 72,000[b]
	Sub-Total	B 128,000
2.	Technology Adaptation and Testing	
2.1.	Salary for Technician/Plant Manager	B 120,000[c]
2.2.	Equipment Purchases	B 200,000[d]
2.3.	Local Fabrication of pilot plant	B 100,000[e]
2.4.	Working Capital	
2.4.1.	Field Test Local Unit	B 100,000[f]
2.4.2.	Production Diversification Trials	B 100,000
	Sub-Total	P 620,000
3.	Capital Fund	
3.1.	Production Credit[g]	
3.1.1.	Soybean Seed Multiplication	B 250,000
3.1.2.	Soybean Production	B 500,000
3.2.	Investment Capital for Rhizobium Plant	B 564,000[h]
3.3.	Start-up Capital Rhizobium Sales and Seeds Service Enterprise	B 115,000[i]
	Sub-Total	B 1,429,000
4.	Technical Consultancy	
4.1.	Product Testing	B 90,000
4.2.	Soybean Market Study	B 20,000
4.3.	Technology Adaptation	B 100,000
4.4.	Commissioning Commercial Plant	B 60,000
4.5.	Soybean Seed Multiplication	B 40,000
4.6.	Soybean Production	B 80,000
	Sub-Total	B 390,000

5. <u>Project Coordination/Management (SVITA)</u>

5.1. Staff Salaries		
	5.1.1. Executive Director	B 60,000[k]
	5.1.2. Small Business Officer	B 60,000[k]
	5.1.3. Finance Officer	B 72,000[l]
	5.1.4. Secretary	B 108,000[m]
5.2. Workshops		B 60,000[n]
5.3. Travel		
	5.3.1. Transportation	B 50,000[o]
	5.3.2. Per Diem	B 36,000[p]
5.4. Office Supplies		B 30,000
5.5. Telephone/Telex		B 30,000
5.6. Reporting/Evaluation		B 40,000
5.7. Audit		B 8,000
	Sub-Total	B 554,000

6. BUDGET SUMMARY

6.1. Market Development	B 128,000
6.2. Technology Adaptation/Testing	B 620,000
6.3. Credit	B 1,429,000
6.4. Technical Consultancy	B 390,000
6.5. Project Coordination/Management	B 554,000
6.6. TOTAL	B 3,121,000 ($ 135,700 @ Exchange rate $1.00 = B23)

B: <u>Budget Notes</u>

a. Seed Group Training

5 groups x 10 persons x 10 days x B16/day	=	B	8,000
Soybean Production Training			
100 groups x 10 persons x 3 days x B16/day	=	B	48,000
		B	56,000

b. Estimated at 24 person-months @ B3,000/mth = B 72,000

c. Estimated at 24 person-months @ B5,000/mth = B 120,000

d. Estimated according the following breakdown:

Autoclave :	B 120,000
Grinder :	B 25,000
Air Pump :	B 25,000
Sieves :	B 15,000
Expendables:	B 15,000
	B 200,000

e. Estimated cost to sub-contract local mechanical workshop to fabricate production equipment.

f. Costs include raw materials, chemicals, electricity, water, rent of space.

g. Production credit calculated according to the following breakdown:

seed multiplication: 250 rai x B 1000/rai = B 250,000
soybean production: 1000 rai x B 500/rai = B 500,000

h. This can be used for two purposes: 1. B 464,000 is earmarked to commission the plant calculated by taking the capital required (B 750,000), less the cost of the equipment in the pilot plant (B 200,000), less the local contribution (15%); 2. B 100,000 to finance fixed assets and/or working capital needs to add new product lines in the plant.

i. This can be used to finance fixed assets and/or working capital. The amount was estimated based on cost of the mechanical thresher (B 100,000) and a storage unit (B 11,500).

j. Estimated according to the following breakdown:

	Fees	Per Diem	Travel	Totals
Product Testing:	50,000	30,000	10,000	90,000
Market Study:	20,000	--	--	20,000
Technology Adaptation:	--	70,000	30,000	100,000
Commissioning Plant:	--	45,000	15,000	60,000
Seed Multiplication:	20,000	12,000	8,000	40,000
Soybean Production:	30,000	30,000	20,000	80,000
Totals:	120,000	187,000	83,000	390,000

k. Six (6) person-months @ B 10,000/mth.

l. Twelve (12) person-months @ B 6,000/mth.

m. Eighteen (18) person-months @ B 6,000/mth.

n. Three (3) at B 20,000 each.

o. Twenty (20) trips @ B 2,500/trip.

p. 120 days at B 300/day.

Evaluation of the project is to be carried out by an expert consultant, Dr. Somasegaran, who will visit in November to certify that the process as designed in Thailand is delivering the organism in the numbers and type as is expected. Dr. Somasegaran will also examine the quality assurance program as well, and make contributions if appropriate. AT International staff will also carry out a formal evaluation in concert with USAID consulting team to measure the efficiency and appropriateness of the project in the country context, according to procedures established with USAID. These procedures are codified in Hyman and Corl 1985.

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SMALL SCALE PRODUCTION OF RHIZOBIUM INOCULANT

IF WE BEGIN WITH A FULLY GROWN CULTURE OF 10^9 CELLS PER ML, THEN:

1000 ML/LITER X 10^9 CELLS/ML = 10^{12} CELLS.

IF, FOR EXAMPLE, WE REQUIRE 50 L OF INOCULANT TODAY, AND WE CHOOSE TO DILUTE AT 50:1, WE WOULD ADD 49 L OF WATER YIELDING 50 L OF DILUTED INOCULANT; THE CELL CONCENTRATION WOULD BE GIVEN BY:

$$\frac{10^{12} \text{ CELLS}}{50 \text{ L} \times 10^{3} \text{ ML/L}} = 2 \times 10^{7} \text{ CELLS/ML}$$

IF 40 ML OF INOCULANT IS INJECTED IN EACH 50 G BAG OF PEAT, THEN 50 L OF DILUTED CULTURE PRODUCE:

$$\frac{50 \text{ L} \times 10^{3} \text{ ML/L}}{40 \text{ ML/BAG}} = 1250 \text{ BAGS,} \quad \text{AND} \ldots$$

1250 BAGS CONTAIN:

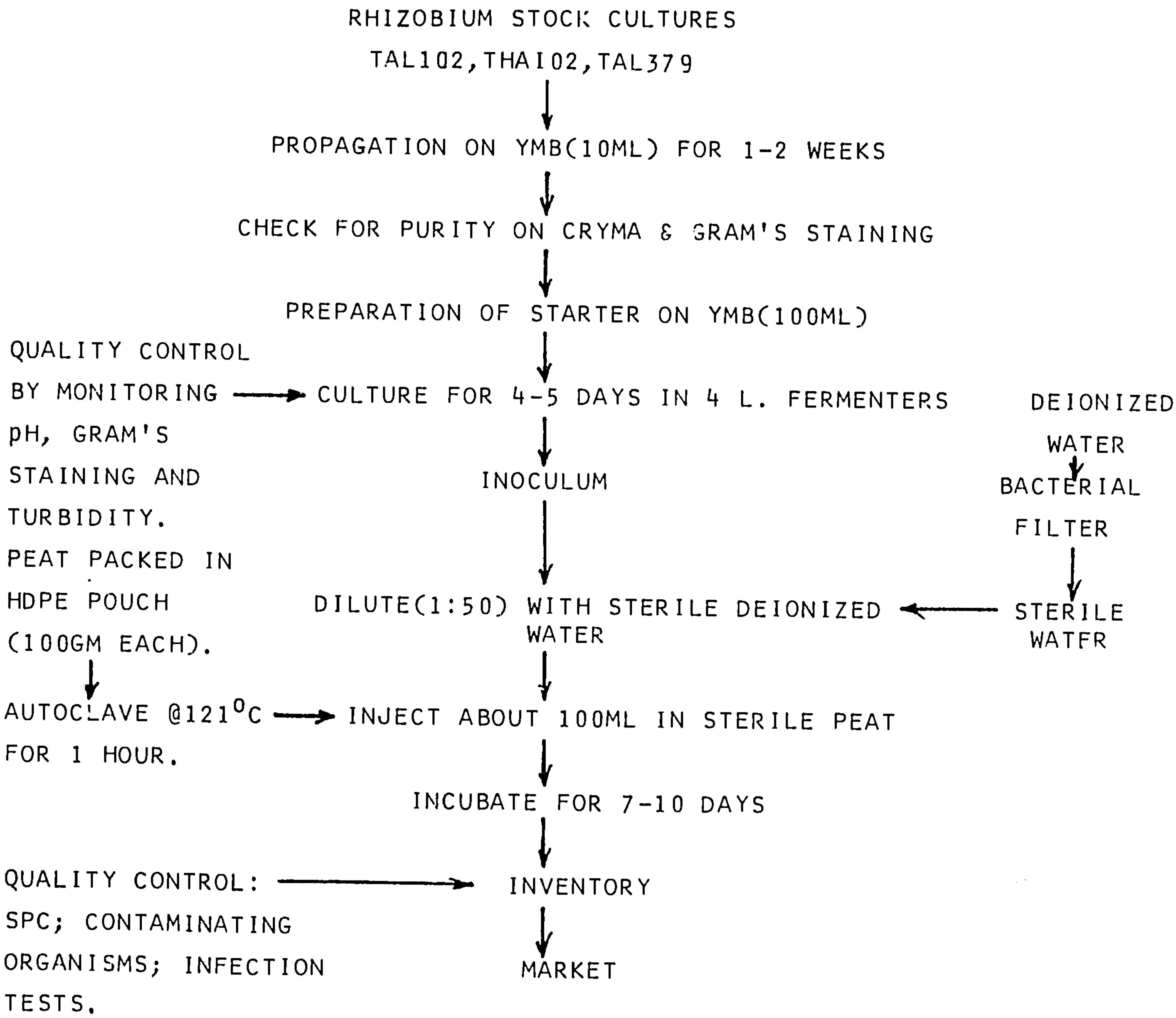
1250 BAGS X (40 ML + 50 G PEAT) = <u>112.5 KG</u> FROM 1 L OF CULTURE.

THIS IS SUFFICIENT INOCULANT FOR 112.5 HECTARES.

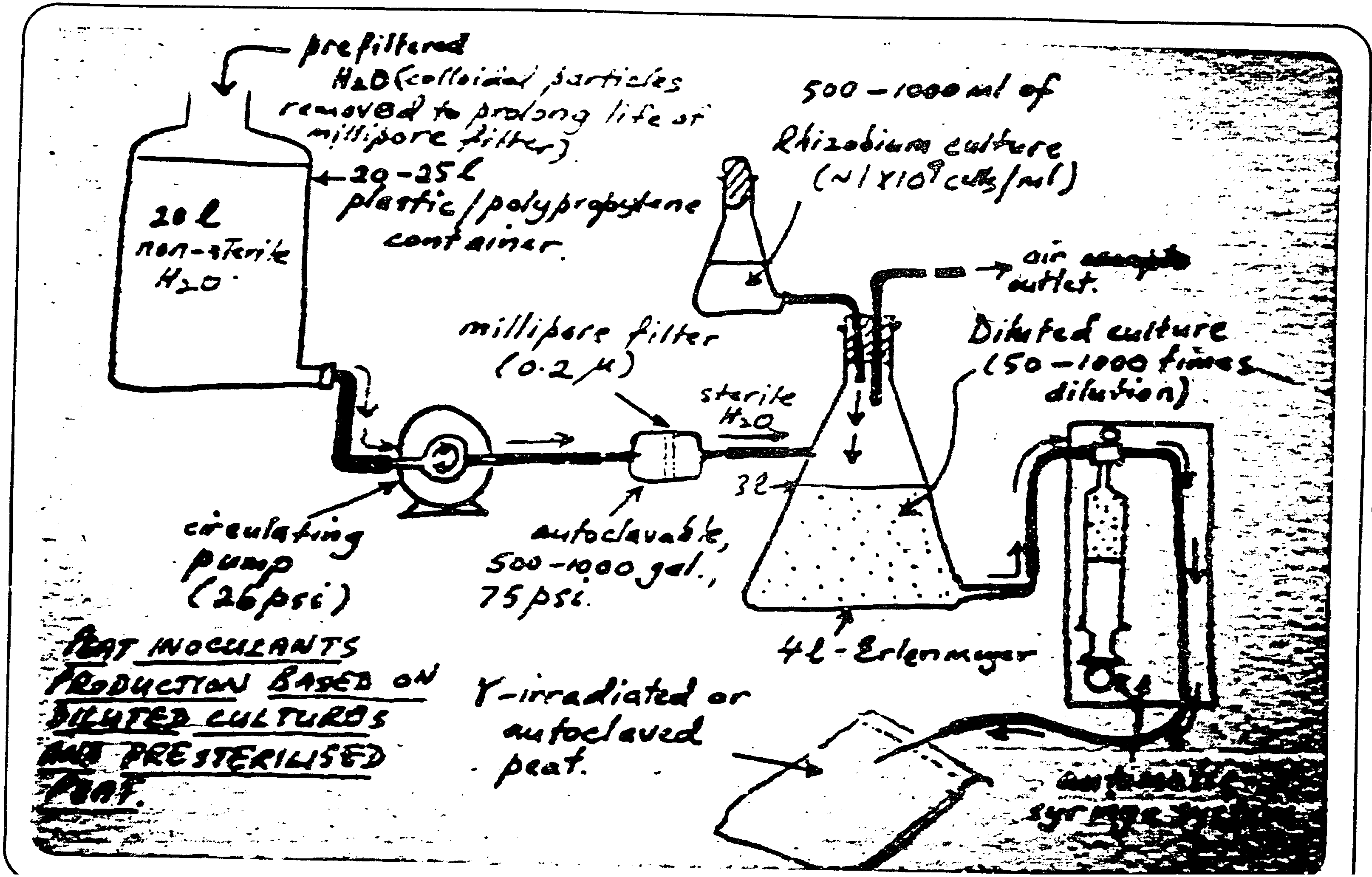
From P. Somasegaran

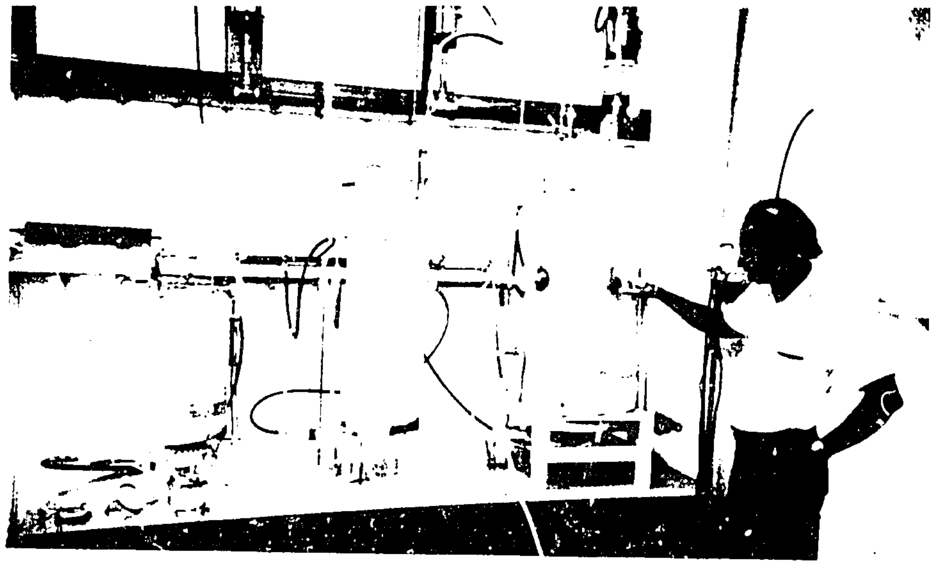
ANNEX 2

FLOW DIAGRAM FOR INOCULANT PRODUCTION



From W. youngmanchai


prefiltered H2O (colloidal particles removed to prolong life of millipore filter)
20-25 l plastic/polypropylene container
20 l non-sterile H2O
500-1000 ml of Rhizobium culture (~1 x 10^9 cells/ml)
air outlet.
millipore filter (0.2 μ)
sterile H2O
Diluted culture (50-1000 times dilution)
3 l
circulating pump (26 psi)
autoclavable, 500-1000 gal., 75 psi.
4 l - Erlenmeyer
γ-irradiated or autoclaved peat.
PEAT INOCULANTS PRODUCTION BASED ON DILUTED CULTURES AND PRESTERILISED PEAT.



P. Somasegaran demonstrates 4, 8,
and 20 l. gas fired fermenter/autoclaves.

P. Somasegaran and J. King, NifTAL Project,
with charcoal fired 4 l. fermenter/autoclave.