International Short Term Consultancy

Final Report to

Programa Cooperativo de Investigacion Agricola para la Subregion Andino
(PROCIANDINO)

Instituto Interamericano de Cooperacion para la Agricultura
(IICA)

Banco Interamericano de Desarrollo
(BID)

Subprograma I - Leguminsosas de Grano

Activity

GENETIC, AGRONOMIC AND PATHOLOGICAL IMPROVEMENT OF THE LENTIL AND FABA BEAN CROPS (MEJORAMIENTO GENETICO Y AGRONOMICO Y PHYTOPATHOLOGICO DE LENTEJA Y HABA)

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February 25 to March 28, 1989

PROCIANDINO Technical Event 2.3.12

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TO IICA/PROCIANDINO/BID

(submitted to IICA Office in Quito, Ecuador)

Subprogram I: Grain Legumes

Activity: Genetic, Agronomic and Pathological Improvement of the Lentil and Faba Bean Crops.

Technical Event: 2.3.12.

I. GENERAL INFORMATION

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B. Institutions Visited: See Appendix 1.

C. Places or Regions Visited: See Itinerary in Appendix 2.

D. Names, Addresses and Working Responsibilities of Scientists That were Contacted: See Appendix 3.

E. Dates and Duration of the Consultancy: February 25 to March 28, 1989.

F. Date of Final Report: October 11, 1989.

II. SPECIFIC OBJECTIVES OF THE CONSULTANT

The consultant will visit faba bean and lentil production areas and researchers in Colombia, Peru, Bolivia and Ecuador, evaluate the current status of these crops in each country, determine factors limiting production in each country and make recommendations for improving production of these crops in these countries.

Primary emphasis will be placed on:

A. Genetic Improvement: Hybridization techniques; breeding and selection methods; yield components; germplasm resources, evaluation and exchange; new varieties; sources of resistance to stresses.

B. Agronomic Improvement: Production systems; rotations; mixed cropping; rate and date of seeding; seeding methods; inoculation with Rhizobium; fertilization; weed control; disease control; insect control; small scale mechanization; pedigreed seed production; quality losses during and after harvest.

Accordingly, the objective of this consultancy is to integrate the current information available on faba bean and lentil breeding and management into a recommended program of action so that IICA can better coordinate the program on improved production efficiency of faba bean and lentil in Colombia, Peru, Bolivia and Ecuador.

III. WORK THAT WAS DONE, RESULTS, CONCLUSIONS AND RECOMMENDATIONS

A. DETAILED DESCRIPTION OF WORK DONE, RESULTS AND CONCLUSIONS BY COUNTRY

1. **COLOMBIA** (February 26 - March 5, 1989)

I arrived in Bogota, Colombia on Sunday, February 26 and visited Tibaitata National Agricultural Research Center in Bogota on Feb. 27. I talked with the Director, Dr. Manzano about grain legumes. I visited Dr. Gomez, Director of Small Farm Cropping Research and Mr. Higuita. They described the climate of Bogota as perpetual spring: 2400 to 2800 m above sea level, about 650 mm precipitation distributed as follows (J-21, F-31, M-44, A-81, M-68, J-58, J-35, A-34, -52, O-102, N-81, D-34) and relatively constant year around monthly mean maximum temperatures of 12 to 14°C. The cool climate delays maturity of most crops. Background information on pea, lentil, chickpea and faba bean is presented in Appendix 4.

a. FABA BEAN: Faba bean is seeded in March-April and again in Aug.-Sept. and about six months is required for maturity. They expressed a need for earlier maturing faba bean varieties. However, this will result in reduced yields. An alternative approach would be to cut the stems after the lowermost pods are black and place them upright in piles shaped like inverted cones to dry. The faba bean seeds are physiologically mature at this stage and thus the rest of the field can be prepared for the next crop much sooner than six months from planting the faba bean. The only precaution is that the piles may rot or the

seeds may sprout if it is too wet to dry within 2 to 3 weeks. Most of the Colombian faba bean crop is grown in 3 states: Cundimarca (Bogota area), Boyaco (NE of Cundimarca) and Narino (Pasto area). Faba beans are often grown near the larger cities where the immature pods are harvested and sold in the markets for green shell faba beans. Some are used for home consumption on the smaller farms to provide a protein supplement for their potato and/or corn based diet. Some faba bean is grown for dry seed for food and planting, but the land near Bogota is too expensive to grow faba bean for dry seed except some for reseeding. The green shell faba bean desired by the market is the broad bean type with a dry seed weight of 2.5 g in the Bogota area and somewhat smaller in other areas. The picked pods retain acceptable quality for 3 to 4 days in the market.

In the home gardens the green shell faba bean is often intercropped with potato or corn or both. The cool climate delays maturity and makes intercropping essential for the campesino so that he can produce both food and a cash crop on his small parcel of land. One campesino plot contained several herbal remedy plants and herbal tea plants for sale as a cash crop. These were interplanted with each other and with squash, coriander, Brassica species (leaves for soup) and many other plants. Faba bean residue was incorporated for its nitrogen as the campesino could not afford N fertilizer.

Colombia has a fledgling nitrogen inoculum (Rhizobium industry and they produced nine tonnes of soybean inoculum in 1988 but none of any other kind. They are testing other strains. Various faba bean plants were checked for nodules, but only a few small, scattered nodules were found and none were like the very large nodules found on faba bean in Canada. This situation was noted also in Peru, Bolivia and Ecuador, suggesting the need for commercial production of Rhizobium specific for faba bean. Similar situations were observed for lentil, pea and chickpea further emphasizing the need for commercial production of various strains of Rhizobium specific to each of these grain legume species (See Appendix 5 for a more detailed discussion).

The major faba bean diseases in Colombia are chocolate spot caused by Botrytis and Fusarium root rot. The major insect pests are the leaf miner and the stem borer. There was some evidence that leaf miner attack may predispose the faba bean to infection by chocolate spot.

The soils in the Bogota area have a pH of 5 to 5.6, 9 to 11% organic matter and are relatively high in N, but low in P, Mg, B and Mo. Several farmers' fields and experimental plots were visited. The plots included row and plant spacing studies, herbicide studies, fungicide studies and insecticide studies. One commercial field had been treated with herbicides and insecticides, but weeds, leaf miners and some virus infected plants were still present. The faba beans were hill planted, 2 to 3 seeds in hills spaced 30 to 40 cm apart and in rows 60 cm to 100 cm apart. The hills are ridged to reduce lodging. This farmer grew cabbage following his green shell faba bean crop and both were high value cash crops. These green shell faba beans all have long pods with 6 to 8 extra large seeds per pod for ease of picking and eye appeal in the market. One corner of the previous faba bean field had been left to produce his seed crop. The expensive land in the Bogota area should stimulate the farmer to cut the seed plot when the lower pods turn black and let it dry.

The field could then be planted to the succeeding crop rather than letting the weeds go to seed as the faba bean seed crop slowly matures under these cool, damp conditions. This will shorten the cropping cycle and increase land use efficiency.

b. LENTIL: Mr. Gustavo Ligarreto, the bean breeder, was also in charge of the lentil program. The production of lentil is limited in Colombia with some grown in Boyaco state. He planned to seed the lentil nursery the next week and so no lentil fields or plots were observed. Only large seeded (5 to 7 mm) yellow cotyledon lentils are grown. Most are planted in October and harvested in February. Major diseases of lentil are caused by Fusarium, Phoma and Botrytis.

c. PEA: Pea is grown at higher elevations around Bogota because it can stand cooler weather than faba bean. Again, most of the pea crop is harvested at the green shell stage and sold in the city markets as a cash crop. The peas also are grown in hills in ridged rows. Ascochyta pinodes is serious under these climatic conditions and all fields are sprayed at least once with a fungicide. Pea is often seeded in January and the earlier seeded fields were poor. Faba bean is seeded in April or so at these elevations after it had warmed up slightly. Pea follows potato in the rotation. The best looking peas were those starting to flower about March 1. Mr. Jorge Velandia indicated a need for a set of differential pea varieties for races of Fusarium wilt. This set of differential varieties can be obtained by writing directly to Dr. John Kraft, Irrigated Agriculture Research and Extension Center, Prosser, Washington.

Mr. Jaimie Osorio indicated a need for plans for a pea sheller. A copy of these plans is presented in Appendix 6.

d. SEMINARS: I gave a seminar on grain legume breeding and management at Bogota and then went to Pasto where I gave another seminar at the Obonuco Research Station.

e. FABA BEAN AT PASTO:

Mr. Oscar Checa was the faba bean breeder at Obonuco and he showed me his plots. Mr. Omar Guerraro, the plant pathologist, also assisted with translation. Grain legume breeding differs from breeding other crops in several respects (Appendix 7). Breeding for yield also requires special consideration due to the large genotype x environment interaction in grain legumes (Appendix 8).

Mr. Checa has an excellent faba bean research program. It consists of a large germplasm collection, F_3 and F_4 populations from the International Center for Agricultural Research in the Dry Areas (ICARDA), and other introductions, F_5 nursery, yield trials of current selections, a study of methods for determining percent natural cross pollination and an extensive diallel crossing nursery. I suggested that he complete his study on level of cross pollination this year and get on with the breeding program. Diallel crosses are used to determine which clonal parent or homozygous parent is the best parent for producing F_1 hybrids or hybrid populations. Since faba bean

is neither vegetatively propagated nor homozygous, the use of diallel crosses in faba bean is of minimal value. Accordingly, I suggested that he forget about doing any further work on the diallel cross. Furthermore, since he had already established that faba bean has a cross pollination frequency greater than 8%, I suggested that he consider it a cross pollinated crop and use the corresponding breeding method. Since pod size and seed size and seed color are important regional attributes of quality, I suggested that he use a population improvement method, specifically the Random Mating Method of Population Improvement as outlined in Appendix 9. I emphasized the importance of a replicated yield test as the basis of selecting lines to include in the next cycle of Random Mating. This process then will require three years per cycle. However, if the plants are increased in Canada between May 1 and October 1, a year can be saved in each cycle and only two years will be required per selection cycle (See details in Appendix 9). An improved variety should be available after 3 cycles (6 years), but 2 or 3 additional years would be required for seed increase and regional yield testing.

Mr. Checa felt that the traits needed in faba bean for the Pasto area were earlier maturity (6+ months to mature), resistance to rust, chocolate spot, Fusarium wilt and/or Fusarium root rot, leaf miner and stemborer.

Mr. Guerrero was screening for Fusarium wilt resistance in both faba bean and pea in the greenhouse. Seedling root tips are dipped in concentrated spore suspension for two minutes and then transplanted to pots. The roots are rated for damage after 4 weeks. Stem borer damage may facilitate Fusarium infection in faba bean.

The faba bean rows are deeply ridged to reduce lodging. The hills are 60 to 70 cm apart in rows 100 cm apart. Maneb is used to try to control chocolate spot. The faba bean can be seeded anytime in the Pasto area. This area is extremely favorable for faba bean (cool and moist). However, these climatic conditions also favor chocolate spot, Fusarium root rot, stem borer and leaf miner. No good level of resistance is known to date and introduced lines usually are damaged more than the local land races. These results further reinforce the utility of using the Random Mating Method to improve the local land races for yield and possibly also for resistance to chocolate spot, fusarium, leaf miners and stem borers. It is quite possible that some variation in resistance to these 4 pests has occurred over the past 300 years of faba bean production in this area. Mr. Checo had a zero till plot where he killed the grass with glyphosate and seeded faba bean in the dead sod. The faba bean plants were poorly nodulated and suffering severe N deficiency. Part of this could have been overcome if the seed had been inoculated with the faba bean strain of <u>Rhizobium</u>, but none is available in Colombia.

The Ipiales substation was visited. This area is the major faba bean producing area of Colombia. About 70% of the faba beans in this area are monocrop and are sold as green shell faba bean in the cities. The remaining faba bean stalks may be grazed which also helps control the weeds. Usually one corner of the field is left to produce dry seed for next year's crop. About 30% of the faba beans in this area are grown in alternate rows with corn and dry pole beans which grow up the corn plants. Some of the corn stalks in this area grow to 3 meters in height. Again, the faba beans are always grown

in hills in ridged rows. These mixed fields of faba bean and corn + pole beans are often used for cash crop plus home consumption.

No pea or lentil fields were evident in March in the Pasto-Ipiales area. Pea is usually seeded in April. Checo evaluates pea populations produced at Medellen, Colombia. There is a working arrangement whereby researchers at Medellen, Colombia produce F_3 and F_4 populations of pea for selection elsewhere in Colombia, Peru, Bolivia, Ecuador and possibly Venezuela. In return, researchers in Bolivia produce F_3 and F_4 populations of faba bean for selection elsewhere in the region. Furthermore, researchers in Ecuador produce F_3 and F_4 populations of lentil for selection elsewhere in the region. This approach has merit, provided the pest problems for each area are properly documented, resistance is available and the proper crosses made. A simple effective method of breeding self pollinated crops such as pea, lentil and chickpea, The F_2-Derived Family Method, is presented in Appendix 10.

Mr. Checa requested data on chemical composition of faba bean, including vicine and convicine contents. He was also concerned by a report of a high incidence of gastric cancer in areas of high faba bean consumption in Colombia and a report in the journal Mutation Research (1984) which reported highly acidic faba bean extracts were mutagenic to bacteria. I pointed out that Egyptian consumption of faba bean is higher than Colombian consumption and they have not reported a high incidence of gastric cancer. In addition, just because something is mutagenic to bacteria does not necessarily prove that it is a carcinogen. For example, caffeine from coffee is mutagenic to bacteria, but this does not deter people from drinking coffee. A table on chemical composition of faba bean is presented in Appendix 4.

Mr. Orlando Monsalve at Obonuco was conducting research on Multiple Cropping Systems with emphasis on off-station demonstration plots. He grew corn in alternate rows with many different crops. Peas and bush beans grew poorly between the corn rows, but the better combinations were rows of corn and pole bean in hills alternated with rows of faba bean or Lupinus mutabilis in hills. He also was studying different row spacings. The best was corn and pole bean in hills on 1 m centers each way with 2 faba bean seeds per hill in between on 1 m centers, but the farmers didn't like it because there was not enough room between the rows to hoe the weeds. He was studying 7 different combinations of crops and row spacings. In one instance faba bean and pole bean were planted together in hills, but faba bean severely suppressed the pole bean. About 12 other multiple cropping systems were being evaluated.

In addition, 5 faba bean lines were being evaluated in alternate rows with corn. Selection No. 4 looked promising to date.

In the Pasto-Ipiales area corn is the primary crop and faba bean is the secondary crop. The monocrop corn yields about 1.5 t/ha and the monocrop faba bean yields about 4 t green pods/ha for an average yield of 5.5/2 = 2.75 t/ha. However, a mixed crop of corn (1.2 t/ha) and faba bean (2.4 t/ha) will yield 3.6 t/ha, much higher. The corn yield is similar and the faba bean production is a bonus.

2. **PERU** (March 6-March 12)

I was met at the Lima airport, taken to the hotel and visited Angel Oviedo Aleman, Director of Research at INIAA, and Alfredo Llona, Advisor to the Director. Labor strikes in Peru resulted in cancellation of my flight to Cajamarca, so they arranged a flight to Cuzco on March 8 instead. The Peruvian coast is largely mountains of rock and sand with 17 narrow valleys where some irrigated agriculture is practised.

I was taken to the La Molina Research Station and talked with Director Adolpho Alcantara, and various researchers including Rufino Montalvo, Leader of the Legume Research Program. INIAA has 22 research stations in Peru, but legume research is limited. North Carolina State University started a program in the 1960s, but it only lasted five years. A new legume research program was started four years ago with most of the research centered at Chincha with highest priority on dry bean and lima bean. Black, red and pinto beans grow well, but the Peruvians prefer a local yellow bean which is low yielding and disease susceptible. Cowpea is adapted to the tropical areas, but the Peruvians will not eat it. A "buffalo skin" bean is preferred and research on it is largely at the La Silva Research Station. Chickpea research is centered at the Vista Florida Research Station and faba bean research is centered at Cuzco. Some research on lentil and pea is being initiated at Huancayo and Cajamarca.

Soybean and peanut research is done at the El Chira Research Station. Research on tarwi (Lupinus mutabilis) is done at Cuzco, Huancayo and Puno. Seed production of these legumes is a problem and thus most of the grain legumes are imported, emphasizing the importance of getting effective grain legume research programs underway. Legumes provide lower returns than other crops due to the high cost of pesticides and low yields. Varieties with resistance to the local diseases and insects are urgently needed.

a. **NATIONAL GERMPLASM PROGRAM**. I met with Eyla Valasco Urquilo, Director of the National Germplasm Program (PRONARGEN) at INIAA. They have extremely limited facilities and their priority crops in order are legumes, Andean crops, tropical fruits, palms and cacao. This national program supports the germplasm banks at the 22 Research Stations. The main collection consists of 35,000 accessions of 85 to 90 species. They desperately need additional support.

Their major emphasis is to:

1. Introduce material from elsewhere. I suggested that they implement a reciprocal change with the United States Plant Introduction Service.

2. Collect native land races and local breeding material to prevent genetic erosion. I strongly supported this approach.

3. Conserve and maintain existing germplasm collection. This aspect is critical since they have limited storage facilities, both short term and long term.

4. Characterize and evaluate the existing germplasm collection.

5. Document the existing germplasm collection. They are currently attempting to organize a data base on a computer system.

They have urgent need for a permanent cold storage unit set at -20°C, complete with a spare compressor and small diesel generator to run the compressor during the many times that the electric power is off. They currently have a small room set at 40°F and 85% RH. They have a replacement compressor, but no way to connect it up. The electricity was off for two weeks recently and seed quality dropped drastically. The director was concerned that, if this happened very many times, the viability of the collection would be lost and all her efforts would be reduced to nothing. I again suggested a reciprocal germplasm exchange with the USDA Plant Introduction Service. Then, if they lost their collection due to loss of proper storage conditions, they could use the USDA collection as a backup or reserve collection and the material would not be lost.

They are considering storing part of the germplasm collection at Tilio which has low temperatures and permanent snow. They may use -15F, and low RH in sealed containers at this site. However, facilities must be built and the collection sampled, sealed and transported there. This may never happen.

They want some tissue culture incubators and training in tissue culture techniques so they can preserve some of their germplasm collection as tissue cultures. Tissue culture techniques can also be used to propagate asexual material and apical meristem tissue culture can be used to free perennials of viruses.

Certain species are unique to Peru-tarwi, flour corn and certain wild potatoes. They are in the process of printing catalogs of their tarwi collection.

b. <u>GRAIN LEGUMES AT CUZCO</u>. I flew to Cuzco on March 8 and met with Vidal Ortez Arriola, Coordinator of the Legume Program for INIAA at Cuzco. He is the bean breeder. The pea and fababean researcher, Roberto Horqque, was at a special course in Pasto, Colombia sponsored by PROCIANDINO and so I missed him.

At Cuzco, October to May is the normal rainy period, but this year the rains were very late and the crops were poor and late. Thus, the campesinos and Indians had thrown rocks and trees on the roads to protest lack of government assistance. This was further aggravated by the two month-long strike of public employees. Thus, the economy of Peru was in bad shape, especially for the campesinos and Indians in the Cuzco area. They staged a major rally one afternoon on the city square of Cuzco. Fortunately, it was peaceful. The local fertilizer plant was closed due to lack of electricity. A local brewery provides extension efforts to assist farmers in growing malting barley. The people also eat barley in the soft dough stage (probably hulless barley).

We drove through the Puyura, Pampa de Anta and Surite area to the Cuzco Research Station at an elevation of 3400 m. June is cold with ice most

mornings. May to early August is the dry season here. The main crops are corn, faba bean, potato, pea and barley with lesser production of oat, wheat, quinoa, tarwi, onion.

I toured Horqque's faba bean plots, courtesy of one of his technicians. They were screening lines from ICARDA and the best ones were being crossed with the local land races. Five parent lines were being crossed with the best of the ICARDA material. The major diseases were chocolate spot, viruses, Fusarium, Cercosporella and rust.

Horqque was also evaluating the Peruvian faba bean germplasm collection consisting of 98 lines, mostly from the Huancayo area. He had several advanced yield trials, a multiple cropping study (three crops alone or in alternate rows with faba bean), a faba bean plant density study (8 different densities), a herbicide trial, an increase of some Mexican lines and some segregating material from ICARDA. Horqque has an intensive and extensive research program on faba bean. The technician suggested that the most important traits in faba bean are: yield, resistance to chocolate spot, large seed size of various colors (depending upon local preference), and earliness. They are also studying market preferences for various types of green and dry faba bean seed.

Cuzco produces flour corn for export. Faba beans are consumed frequently: green in the city markets and dry by the campesino.

The land tenure system is that after land reform the farmers got about 6000 to 7000 m^2. The older sons go to town and learn a trade and the youngest son gets some land when he marries.

Horqque also had some pea yield trials and the station had some seed fields of tarwi and quinoa.

c. **THE WEST GERMAN JOINT PROJECT ON PERUVIAN CROPS (COPACA)**. I visited the West German project on Peruvian Crops at Cuzco. They started a 10-year project in 1985, consisting of three phases:

1. Pilot phase - 3 years in 2 districts with 23 communities

2. Consolidation phase - 4 years starting in Sept. 1988. The techniques proven in the pilot phase are extended to 50 communities.

3. Massive Multiplication phase - During the last 3 years of the project, the results, techniques, etc., developed by this project will be disseminated throughout Peru, largely by the Peruvian government, if everything proceeds according to plan.

The primary objective of the COPACA project is to promote use of Andean crops (quinoa, amaranthus, tarwi, pea, faba bean and "wheat") to help improve the diet of the campesinos and Indians in areas above 3500 m. These crops are used to improve the protein content and quality of their potato diet.

The COPACA project consists of four departments:

1. Agriculture - This department is used to realize their objectives. It consists of several programs:
    a. A Credit Program - This is used primarily for seed with payment in kind (or a similar product). Over 250 farm families are participating.

    b. Agricultural Extension Program - This involves all aspects of crop production. They are trying to develop recommendations for these ecological conditions and get these practices adopted. They have 6 agricultural extension workers in 2 districts plus a nutritionist and a social worker. Emphasis is on a strategy that can be adopted without additional staffing.

2. Nutrition Education

3. Community Development

4. Multiplication of Strategies and Methods.

Specific projects include such things as integrated pest management, control of chocolate spot on faba bean and many others.

The COPACA project is considered a special project by the German government and as such it is fairly flexible in how it develops. It is doing an excellent job.

d. **CANSAVE IN CUZCO**. I heard that CANSAVE had an office in Cuzco so I availed myself of the opportunity to visit them and see for myself the kind of work they are doing. Their primary objective is to improve the living style of the campesino by:

    1. Teaching - They teach reading and writing to all ages.

    2. Providing medical help - They emphasize natural remedies and vaccinations.

    3. Improving sociological aspects.

    4. Assisting in arranging credit through the Agricultural Bank.

    5. Working with mothers' clubs to develop better balanced diets, etc.

    6. Working with other institutions assisting orphans.

    7. Helping plan and organize construction of homes, schools, reservoirs, irrigation ditches, etc. including provision of potable water.

    8. Developing leadership ability in some of the campesinos.
    CANSAVE is doing a good job in Cuzco.

3. **BOLIVIA** (March 12 to March 18)

a. THE PAIRUMANI RESEARCH STATION. I flew to Cochabamba on March 12 and spent much of my time at the Pairumani Research Station where they are conducting research on beans, corn, durum and amaranth with some faba beans at the higher elevations. I reviewed several written reports by Mario Crespo who was attending a training meeting in Pasto, Colombia, sponsored by PROCIANDINO. Luis Pierola, the wheat breeder, served as the local host.

Cochabamba is on a medium large plain at 2500 m elevation. It receives about 700 mm annual precipitation with a dry period from mid-April to mid-August.

I toured the Germplasm Bank storehouse at the Pairumani Station. It is maintained at 4°C and 40% RH. They recently received two new deep freezers for long term storage. Under their storage conditions they have to grow one-third of the collection each year. The deep freezers will extend the interval between increases to 10 or more years. The crops they concentrate on are faba bean (local land races), peppers, cucumbers, durum wheat, Phaseolus, tarwi and flour corn.

The Corn Breeding program at Pairumani has three major projects: (1) Population improvement of flour corn including intervariety hybridization, (2) Introgression of opaque-2 into feed (dent) corn, and (3) Dent corn for livestock, primarily for dairy cattle and chicken layers. Plans are to establish a seed production center next year to increase and process seed of new varieties. The major diseases of corn are caused by Helminthosporium, Fusarium foliar infection and stalk rots. Insects transmit a mycoplasm to corn. Late corn varieties are seeded in early December. Two corn crops per year can be grown at the lower elevations since there is no dry season there. At elevations below 3000 m there is increased interest in introduced dent varieties, while flour corn is grown primarily at the higher elevations.

Crop rotations in the Pairumani area include:

(a) Maize-wheat in year 1 and barley/wheat-potato in year 2.
(b) Faba bean-maize-wheat/barley.
(c) Faba bean-wheat/barley.
(d) Early potato-early maize-wheat/barley.

In the best soils under irrigation the rotation often consists of potato-maize-faba bean. On dryland areas there may also be continuous wheat, barley or wheat followed by barley. The potato crop is the major cash and food crop at the higher elevations, so the campesinos fertilize the potato and grow corn on the residual fertilizer. In the tropical areas, soybean is the major crop. It is crushed for oil. The soybean is usually followed by dent maize for livestock feed.

Jaime Argote, the Corn Breeder, is using introduced corn with wide adaptation and the opaque 2 gene for feed corn. The flour corn is grown primarily at the higher elevations.

Dry beans are grown here also and there are many different size and color

combinations in the seeds. Tarwi is grown only at the higher elevations. It averages about 37% protein and 18% fat, but precautions must be taken in preparing it for food. Apparently, a water soluble compound (alkaloid ?) must be removed by soaking the seeds overnight and discarding the soak water.

Cochabamba is on a medium large plain at about 2500 m elevation. The rainfall pattern is characterized by an extremely dry spell from mid-April to mid-August. This is one of the reasons that the Germans have a major irrigation project in this area. The average monthly precipitation is something like this: J - 167 mm, F - 151 mm, M - 99 mm, A - 30 mm, M - 1 mm, J - 0, J - 0, A - 25 mm, S - 18 mm, O - 12 mm, N - 97 mm, D - 95 mm for a total of about 700 mm.

b. <u>THE MISION TECNICA ALEMANIA (Gesellschaft fur Technische Zussamenarbeit (GTZ), Programa de Riego Altiplano/Valles (PRAN)</u>

The German (GTZ) project involves development of an irrigation system called the Punata Irrigation Project. It involves about 5000 ha and over 3600 farm families are involved. The German Government is involved in building the dams, the water distribution system and the drainage system. The GTZ project itself is involved primarily with the agricultural aspects of the overall irrigation project.

Dr. Ranier Rothe was the German Irrigation Specialist who was in charge of the agricultural project and he gave me a special two-day tour. This project is very well managed and is doing excellent work. The Irrigation Project employs 52 staff and is organized into four sections:

1. Agricultural Production and Irrigation (at the field level).
2. Operation and Maintenance of the Irrigation System.
3. Agricultural Economics: Evaluation of the benefits and results of irrigation so as to better justify recommendations.
4. Extension: Four specialists at the present time with more to follow. These specialists are well trained local people, some who are working on an advanced degree.

In addition, there are two other cooperating units involved in (1) Communications and (2) Monitoring and Evaluation of the project and all work together.

Initially, we toured the San Benito Research Station of Instituto Boliviano de Tecnologia Agropecuario (IBTA), which specializes in irrigated fruit crops and cereals, but they are expanding their program to include vegetables with help of Japanese foreign aid assistance. There are about 14 IBTA Research Stations in Bolivia.

Some chickpea variety and seeding date studies were grown here under irrigation. I advised them about the seed-borne ascochyta blight problem in chickpeas and how devastating it can be with sprinkler irrigation or frequent rain showers to spread the inoculum to adjacent plants. I also warned about the problem of planting kabuli (large seeded) chickpea into excessively wet

soil. A high frequency of seed rot can occur if oxygen is limiting (excess water) during the first 24 hours of water uptake by the freshly planted seed. I also pointed out that chickpea has a deep and extensive root system that enabled it to grow better than most crops during prolonged drought. In addition, chickpea is extremely sensitive to poorly drained or water logged soils and a high frequency of root rot will occur under these conditions. It appears that the best approach with chickpea is to thoroughly wet the soil profile to 1.5 to 2 m before seeding and then irrigate only 2 to 3 times during the flowering stage since additional moisture will aggravate disease problems sooner or later.

Some lentil variety and spacing studies were grown under irrigation on the San Benito Research Station. The lentil plants were spaced 30 cm apart in rows 50 cm apart. I suggested that they try to increase plant density from the current 9 plants/m^2 to as high as 60 plants/m^2. I told them that under dryland conditions in Canada we often plant lentil 5 cm apart in rows 15 cm apart or up to 120 plants/m^2. However, under irrigation with a long growing season the plant population could be reduced materially, provided weed control was effective. A denser population would hasten maturity if the irrigation supply was restricted in the latter part of the pod filling stage. Excess water at this stage may result in Sclerotinia and/or Botrytis infection of the vines in contact with the soil. Rain or sprinkler irrigation during the final stages of maturation also will severely discolor the seed coats and result in downgrading of the lentil crop.

Some beans were also grown in irrigated plots at the San Benito Research Station. Beans are actually a new crop to this part of Bolivia. They were studying different support systems for the pole beans: corn, stakes or poles. The emphasis here was for the snap or green beans. They had to spray twice for aphid control.

Some faba beans were also grown in the irrigated plots at the San Benito Research Station. They were seeded late (in January, rather than October) to reduce the incidence of chocolate spot. These faba beans are large seeded and have long pods holding 6 to 10 seeds (6 was the most I saw).

Some pea plots were also grown under irrigation at the San Benito Research Station. They are using Petit Pois pea, but this is a generic term applied to an array of medium- sized green cotyledon peas that are usually grown for the fresh pea market. Normally the campesino will get three hand-picked harvests from his pea crop. However, hand picking in a densely seeded field wrecks the vines for subsequent pickings. The seed is normally broadcast and then the field is plowed with a pointed stick plow to cover the seed. It is difficult to hand hoe the weeds in a broadcast crop and so some effort is being taken to evaluate row culture. Pea usually follows potato in the cash crop rotation. Pea is the second most important grain legume in Bolivia (after faba bean), but very little research is being done on it. It is an important market garden crop in areas adjacent to the cities at the higher elevations. Perhaps greater emphasis should be placed on pea production and research in Bolivia.

Related to the testing and increase of seed of new varieties of various crops at Pairumani, in the GTZ project and the IBTA Research Stations is the

need for improved training and facilities for pedigreed seed production. Some of the more progressive farmers must be involved in the pedigreed seed production program, if they are not already involved. Training for Extension personnel is available at many agricultural universities in the U.S. and Canada. Suggestions on a pure seed program are presented in Appendix 11.

About 80% of the population of Bolivia consisted of campesinos who are largely subsistence farmers. The GTZ program is emphasizing Crop Diversification - pea, lentil, chickpea, flowers, snap bean, etc. Crop diversification should help the campesino spread his risk and stabilize his income with less reliance on a one crop economy.

The year 1988 was excessively dry and many of the irrigation reservoirs are nearly empty as they prepare to go into the dry season (May to August 1989).

Bur clover and annual sweetclover were grown as an understory in some corn fields. They fix N and benefit the corn as well as the succeeding crop. In addition, they provide some forage for the dry season. Legumes help increase self sufficiency of the crop rotation in this way.

GTZ gets its recommendations from the Pairumani Research Station. These practices are tested and results given to Pairumani for further refinement.

c. THE PUNATA IRRIGATION PROJECT. West Germany is providing credit (about $15 million) to pay for the dams, canals and the drainage system (yet to be defined). The operation is based on donations (money and payment in kind) from other organizations and IBTA. The program as three main phases:

1. Orientation - 5 years.
2. Implementation - 4 to 5 years.
3. Transfer - 1 to 3 years. GTZ staff will be reduced and operations turned over to the local irrigation districts and IBTA. The districts must assume management as the government does not have adequate funds. Local input and management is essential if development is to become self sustaining.

One reason crop diversification is being stressed relates to the narcotics industry along the tropical lowlands. It generates over $200 million per year. About twice this amount will be required to replace narcotics with a crop diversification program. One approach would be for the growers to lobby the government for a tariff on imported crops that are well adapted to Bolivia. This would then give the Bolivian farmers some incentive to produce these crops for the local markets without fear of being undersold by cheap imports.

A sweet corn-snap bean demonstration field was visited. The corn and beans (pole type) were seeded together in hills, The snap beans and sweet corn were hand harvested for the local market and the remaining top growth was chopped for silage for a local dairy. This combination gave an excellent return.

USAID provided credit to a flower growers cooperative so that members could

establish roses and carnations and build plastic greenhouses. However, they still have the problem of trying to sell into a closed market controlled by a few large producers. Perhaps a cooperative marketing association will help break into the market.

The center of faba bean production in Bolivia is at Colomi. Chocolate spot is the main problem since it is favored by maximum temperatures of 18-20°C and RH greater than 80%, as is found here. Cobox or copper sulfate sprays provide some control. Other diseases include rust and Alternaria black spot. Fusarium and Rhizoctonia root rots are favored by excessively wet, poorly drained and compacted soils (poor aeration). There is no leaf miner problem in this area of Bolivia, but the stem borer is a problem in wet areas, as is the cutworm (Agrotis sp.). They also have a fly that lays eggs in the mud and the resulting larvae eat the faba bean roots. The severity of this problem has not been determined.

A second irrigation project is the Tiraque Project, consisting of 2000 ha at 3200 to 3500 m elevation. The irrigated pea and faba bean crops looked good here. The demonstration plots were planted in cultivated (by hand) rows and had been fertilized and sprayed with pesticides to control diseases and insects. It was estimated that the Petit Pois peas would produce 5 t/ha of green pods. Some corn spurry plants (very competitive weed) were noted in the pea fields. The peas in the Colomi area are primarily for seed production. The peas for pods for the city markets are grown at the higher elevations. November was usually the best month for seeding peas in this area and they were in full bloom by mid-March. I suggested that they irrigate this pea field only once more so as to keep diseases and root rot to a minimum. It was an outstanding field with very few weeds and 6 pods per stem were already set. The manager was considering 2 to 3 more irrigations, so I don't know if I convinced him or not. The pea rows were 50 cm apart and the rows consisted of hills (3 seeds/hill) spaced 20 cm apart. The seeding rate was 60 to 70 kg/ha.

Many farmer fields were low in N and N-deficient non-nodulated pea and faba bean plants were readily apparent. The outstanding demonstration pea field had been fertilized with 20 kg N/ha and even here some N deficient, non-nodulated plants were evident. I suggested that they should have a Rhizobium inoculation demonstration, but they said it was extremely difficult to import viable Rhizobium into Bolivia and to keep it viable after it had been imported. I suggested that they have some combination treatments of seed-placed phosphate fertilizer (See Appendix 12) plus Rhizobium inoculated seeds of pea and/or faba bean in some of their demonstration plots. Perhaps a small Bolivian legume inoculant production could be developed, patterned after the Colombian soybean inoculum test project.

d. SEMINARS. I gave three seminars while in Bolivia, one at Pairumani, one at the GTZ operations center and one to some staff and students from the Departmento de Fitotecnia, Universidad Major de San Simon who came to the Pairumani city manor for the seminar.

e. FABA BEAN. In the Altiplano it is usually the smaller farmers that plant faba bean since it is used as a subsistence crop along with potato. Around the larger cities faba bean is grown for the green pods which are sold

as a cash crop. In the Altiplano the larger farms grow wheat (durum largely), especially on soils that are too poor to grow other crops.

Pairumani is trying to establish a faba bean-wheat rotation in the Altiplano, but this will require a large market for dry faba bean seed, possibly an export market in Japan. Some faba bean is also grown around La Paz at Lake Titicaca.

Pairumani is trying to expand its program for the production of Breeder seed of their new varieties, but they need a relatively small scale portable seed cleaner. Perhaps they would be interested in the Gjesdal Mini Five in One rotary seed cleaner distributed internationally by Carter Day Ltd., P.O. Box 488, Winnipeg, MB Canada R3C 2J6. This cleaner can be mounted on a two-wheel trailer or a small pick up truck.

In the absence of Mario Crespa, the Faba Bean Breeder, I reviewed some of his research progress reports. He reported comparing yields following several cycles of mass selection in faba bean. The yields fluctuated but in most cases it appeared that he had made some progress in increasing yield, but not to the extent expected from that many cycles of selection. It appeared to me that he was not practicing severe enough selection for seed yield. Thus, one cannot successfully select for yield without having run a replicated progeny test and using remnant seed of the highest yielding progenies to start the next cycle of random mating and selection. For more details on this proposed approach, see Appendix 9. This approach takes three generations per cycle of selection, but each cycle can be reduced to two years if an increase generation prior to yield testing is grown in Canada from May 1 to October 1. A cooperative project involving an off-season increase in the Northern Hemisphere will increase efficiency of the faba bean breeding program.

Since local land races of faba bean have the desired seed size and seed coat color, it is appropriate to start a population improvement program in each of several of the more promising land races in each Altiplano country. The 300 years of natural selection in various land races appears to have resulted in some tolerance to diseases such as chocolate spot and presumably also some of the insect pests. Introgression of several widely separated land races should permit selection for a higher level of resistance, possibly just by increasing selection pressure for seed yield using the Random Mating Method (Appendix 9). I would be glad to try and set up some sort of off-season increase of random mating lines from at least one population so that enough seed would be available for a replicated yield test the second year in the Altiplano.

4. **ECUADOR** (March 19 to March 26)

On March 19, I flew to Quito, Ecuador and was met by Dr. G. Hernandez-Bravo. At the Instituto Nacional de Investigaciones Agropecuares (INIAP) and the Instituto Interamericano de Cooperacion para la Agricultura (IICA), I met Jose Acuna, Legume Coordinator and B. Ramakrishna, Acting Director of IICA and Extension Specialist. INIAP is conducting research on five grain legumes:

1. Bean (Acuna - 25%).
2. Lentil (Acuna - 25%).
3. Faba bean.
4. Pea.
5. Tarwi.
6. Some preliminary evaluation work on chickpea also.

The Grain Legume program is supported by other researchers:

A. Plant Pathologist (plus some microbiological work).
B. Weed Control - post emergent metribuzin works well.
C. Soils.
D. Entomology.
E. Agricultural Mechanization - Primarily limited to some minimum tillage studies in faba bean.

Edmundo Cevallos coordinates the plant breeding projects in all five grain legumes and coordinates the yield trials.

Jose Vasquez heads the germplasm bank and assists the others.

Jose Pinzon, Agronomist, heads the off-station variety trials. These three individuals and Jose Acuna showed me around the plots on the Santa Catalina Research Station and elsewhere.

a. FABA BEAN. As noted in the other Altiplano countries, there is a strong need for earlier maturing varieties of faba bean. Most local varieties require 220 to 240 days to mature. I suggested that they consider cutting the plants and letting them dry in small piles as soon as the lowermost pods turn black since most seeds are physiologically mature at this time. This would release the field for planting the subsequent crop.

The objectives of the faba bean research program are to: (1) Evaluate local land races and introduced germplasm (93 local races, of which the best 10 are in yield trials, and 300 introductions), (2) Develop improved varieties, and (3) Evaluate international screening trials from ICARDA. In their pure seed program they have one hectare increases of each of four new faba bean lines. One or more may become a new variety. The best selections are in replicated yield trials at four locations.

Faba bean introductions are evaluated for resistance to chocolate spot and rust. Selection also is for early lines and large seeded lines. Twenty promising lines from Colombia are being evaluated (this interchange of breeding materials among the Altiplano countries should be strongly encouraged for the mutual benefit of all countries). Lines from Bolivia and Peru do poorly in Ecuador due to susceptibility to chocolate spot and viruses. The 10 best Ecuadorean lines of faba bean are currently in third year of testing at four sites: Chimborozo, Bolivar, Carchi and Pinchincha, where most of the faba beans are grown.

Other faba bean materials being tested include several plant rows of selections from promising materials. They select the best rows and then the

best plants. This is the traditional pedigree system as used with self-pollinated crops. I suggested that, since faba bean was a cross pollinated crop (at least to some extent), they should use a population improvement method such as the Random Mating Method (see Appendix 9).

They are also evaluating some determinate faba bean lines from ICARDA. They are working closely with ICARDA in both a training program and evaluation of international nurseries. This type of cooperation should be strongly encouraged with ICARDA. Also, some cooperative program should be established with the University of Saskatchewan, perhaps with International Development Research Centre (IDRC) support.

In Ecuador, Alternaria and rust are more important than chocolate spot. Leaf miners are a problem, but no one mentioned stem borers. They found a new insect this year (Naupactus sp.) that cuts semi-circular leaf notches. It is not known how serious this insect may be.

Faba bean stalks are sometimes used for fuel. This practice should be discouraged if a reasonable substitute fuel can be found because of the forage value of the stalks, their N content and the beneficial effect they have on soil tilth and organic matter levels.

Rhizoctonia is an important disease on lentil, pea and faba bean due to poor soil aeration and the short cycle between susceptible crops. They should screen large segregating populations and introductions for intermediate levels of resistance which may then be intercrossed to produce higher levels of resistance. Distinction should be made between resistance to the seed rot and resistance to the root rot. Fungicidal seed treatment may prevent seed rot, but usually has little effect on root rot (Appendix 13).

Potato is the main cash crop, but 5 to 6 months is required to mature the crop. Farmers may grow a second potato crop or faba bean after the potato crop. Since both are susceptible to Rhizoctonia, this disease builds up rapidly and in wet years it can be very devastating. One field trial site of lentil and pea at Tumbaco was essentially wiped out by Rhizoctonia.

Seed treatment with PCNB reduced Fusarium root rot of faba bean but increased Rhizoctonia root rot relative to last year. However, the previous crop was potato last year and this year the previous crop was cereal, so this is not really a valid comparison.

b. LENTIL. They are evaluating over 160 introductions and the best ten are grown in replicated yield trials. They released Precoz from Argentina as INIAP 406 in 1987. Lentils are not grown on the Santa Catalina Research Station as it is too wet for them there.

Lentil production has dropped in recent years due to Fusarium and Rhizoctonia root rots in the cool wet climate of Ecuador. These diseases become serious rapidly in wet, poorly aerated soils with short cycles between susceptible crops. INIAP 406 lentil does well in Bolivar province due to its early maturity. People prefer larger seeded varieties than Precoz, even though it has a 1000-seed weight of 68 g when grown in Ecuador. Reselections

are being made in some promising selections from Chile that are segregating for earliness.

Lentil plots at Tumbaco were completely wiped out by Rhizoctonia (over 30% of the plants were dead at the first bloom stage in an increase plot of INIAP 406 (Precoz)). Two types of symptoms were present, depending on the variety: yellowing of the foliage and bronzing of the foliage. Some lentil lines from ICARDA have a fair level of resistance to Rhizoctonia: ILL 1939, ILL 5699, ILL 5821, ILL 4400 and F_3 populations of ILL 2624 x ILL 3458, ILL 5588 x ILL 5520, ILL 39 x ILL 784, ILL 500 x ILL 784, ILL 1 x ILL 262 and ILL 486 x ILL 193. I suggested that they select 5 early plants from each resistant F_3 population and screen these F_3 derived F_4 rows for Rhizoctonia resistance at this natural "hot spot" again next year.

Two new lentil varieties from Argentina, Silvana and Natalia, are being tested. They are derived from a cross between Precoz and a large seeded line. They are early and large seeded.

The lentil plots were fertilized with 27-27-0 broadcast prior to seeding. Seed was treated with PCNB plus Lorsban (cutworm preventative). The field was treated with 1 kg/ha Afalon (linuron) for weed control. It was dry right after seeding and the plants were stunted. Then the rains came and Rhizoctonia root rot became devastating. I suggested that metalaxyl is an excellent fungicide for seed rot and other diseases caused by Phycomycetes.

At Tumbaco (elevation 2400 m) the annual mean temperature is 17°C vs 11°C at Quito. The annual precipitation is 962 mm with a dry June, July and August and peak rainfall in March and October. The pea and lentil plots were seeded in mid-January and will be harvested in late May - early June. I suggested that, since lentil has good drought tolerance, perhaps they should seed lentil in mid-February and let it mature during the July drought period. I suggested that they test this suggestion by planting pea and lentil every two weeks between mid-January and March 1.

They were also testing 30 rust resistant lentil lines from Chile, mostly crosses with Laird lentil from Saskatchewan which is immune to the Chilean races of lentil rust. The 10 best lentil lines were grown in the Regional Lentil Variety Test for the Andean Region. Lentil line E112 (#54 from Washington) also had good Rhizoctonia resistance.

c. PEA. ICARDA distributed its first International Pea Adaptation trial to the five IICA countries in 1988-89. The pea plots at Tumbaco were devastated by Rhizoctonia. The plots were seeded thinly in 4-row plots, 2 m long with 60 cm between rows and 20 cm between hills in a row and 2 seeds per hill. This is about 33% the seeding density used in Saskatchewan on dryland. However, irrigated peas with a long growing season can largely compensate for this thin stand. Only three lines in the ICARDA Pea Adaptation trial exhibited a low level of resistance to Rhizoctonia (Syria Sel. 1690, Ecuador 063 and ILP 974).

d. GRAIN LEGUMES AT SALACHE. Salache is a drier, warmer site with lighter soil. There was only a trace of Rhizoctonia on lentil here. A kabuli chickpea increase of California INIA from Chile looked good, but there were no

nodules since chickpea had never been grown here before and it was not inoculated. I made the observation that many legumes were failures in new areas due to planting them in low nitrogen soils without inoculation with nitrogen fixing bacteria. I also suggested that they treat all kabuli chickpea seed with metalaxyl before seeding for seed rot control. They used Captan seed treatment and had over 50% emergence (at least 1 plant in each 2-seed hill).

The farmer cooperator at the Salache site was a pedigreed seed grower. He had seed increase fields of 2 bean varieties, 2 potato varieties and 1 lentil variety. The rows was planted on ridges and the plots were irrigated. He had an oat-vetch mixture for pasture and soil improvement.

There was severe soil erosion in an adjacent area. It was totally denuded and had many deep gullies. It was land that no one was responsible for and so it was abandoned after the erosion became severe.

e. SEMINAR. I gave a seminar on breeding and management of grain legumes at the Santa Catalina Station, INIAP.

f. BACKGROUND ON PROCIANDINO. Dr. G. Hernandez-Bravo provided me with background information on PROCIANDINO. PROCISUR, a cooperative agricultural research program among Brazil, Bolivia, Uruguay, Chile and Argentina, was started about 1983 with support fom IICA and BID and has made good progress.

The idea of a cooperative agricultural research effort among the Andean countries arose about 1975, but it was not until October 1986 that PROCIANDINO was organized for training and research in agriculture with a $2.8 million grant from IDB, $250,000 from each of the 5 countries (Columbia, Venezuela, Bolivia, Peru and Ecuador) and IICA support for communications fo the first three years (1986 to 1989). CIAT, CIP and CIMMYT are also involved in cooperative and training programs. The costs and benefits of agricultural research are reviewed in Appendix 14. The relative merits of agronomic and plant breeding research are discussed in Appendix 15.

PROCIANDINO held its first meeting in December 1986 and established four sub-programs:

1. Edible oil crops (oil palm, peanut, soybean, sunflower and sesame).
2. Potato.
3. Maize.
4. Food legumes.

They also established a 3-year program at this meeting:

1. Established an international coordinator and associate coordinator for each of the above sub-programs. Dr. G. Hernandez-Bravo is the only full-time international coordinator and is reponsible for the Food legumes sub-program. The Associate coordinator (Food legumes) is at CIAT.
2. Established a national coordinator in each country.
3. Scheduled three short term consultancies:

(a) Root Rots of Grain Legumes (Oct.-Nov. 1987) - Dr. George Abawi.
(b) The Andean Pea Crop (Oct.-Dec. 1987) - Dr. Earl Gritton.
(c) Lentil and Faba Bean in the Andean Region (March 1989) - Dr. Al Slinkard.

PROCIANDINO currently has 22 cooperative projects, four of them on Grain Legumes. A fifth grain legume project on black beans involved only two countries and was subsequently dropped due to the requirement for a minimum of three cooperating countries. The four grain legume projects are:

1. Faba Bean: Production of Segregating Populations of Faba Bean with Resistance to Disease and Insect Pests. Peru is the lead country and the coordinators are Vidal Ortiz and Roberto Horqque. The other cooperating countries are Bolivia, Ecuador and Colombia. Germplasm is being evaluated and developed in Peru and is being tested in the other cooperating countries. All cooperating countries should be encouraged to make collections of local land races, increase them and exchange them with the other cooperating countries and evaluate them for adaptation to their conditions and reaction to their pests.

2. Lentil: Collection, Evaluation, Conservation and Distribution of Lentil Germplasm. Ecuador is the lead country, Jose Acuna is the coordinator and the other cooperating countries are Colombia and Peru. No breeding is involved to date. The best lines from local races and introductions are increased and entered into the Andean Regional Lentil Yield trials every other year (1987-1989-1991). INIAP 406 (Precoz from Argentina) was developed for Ecuador through this program.

3. Pea: Production of Segregating Populations of Pea with Resistance to Disease and Insect Pests. Colombia is the lead country, Mario Lobo at Medellen is the coordinator and the other cooperating countries are Peru and Venezuela. Colombia has had a pea breeding program for over 10 years and has graciously supplied three F_4 populations to the cooperating countries to screen promising selections. The best selections were entered into the 1988 Andean Regional Pea Yield Trials in 1988-89. They recently started on this new program and will have new F_3 populations available for distribution in 1990. All cooperators should be encouraged to contribute their land races to Colombia so that these adapted lines can be incorporated into segregating populations and contribute to the germplasm pool. Additional introductions should be obtained from Russia, Poland, China and Sweden, to name a few countries, in order to further expand the available germplasm pool.

4. Faba Bean: Study, Identification and Control of Disease and Insect Pests in Faba Bean. Bolivia is the lead country, Mario Crespo from Pairumani is the coordinator and the cooperating countries are Ecuador and Peru. The primary objective is to develop effective control methods and print a bulletin on this subject for distribution. At a training course in March 1989 the cooperating researchers from the various countries assigned primary responsibility for screening for resistance to certain disease and insect pests of faba bean to a specific country.

(a) Colombia - rust, stem borers.
(b) Peru - chocolate spot, viruses.
(c) Bolivia - root rots.

(In addition, Ecuador was assigned responsibility of screening for rust resistance in lentil).

To date, two workshops have been proposed to ICARDA. One workshop should involve a pathologist, entomologist and a plant breeder for 3 to 4 weeks. The second workshop should involve an ICARDA scientist collecting local land races of pea, lentil and faba bean and to increase, characterize, distribute and evaluate them. In particular, there is a great storehouse of genetic variability in the faba bean that can be used elsewhere in the world. In addition, the low levels of pest resistance in the land races of faba bean should be combined to produce higher levels of resistance and multiple pest resistance. I suggest that the GTZ mission at Cochabamba, Bolivia be involved more directly as a cooperator to help evaluate some of the new lines of food legumes. They are promoting crop diversification and this certainly includes some of the food legumes in many areas.

A short discussion of the preliminary recommendations with Dr. G. Hernandez-Bravo concluded the consultant's working tour of the four Andean countries, Colombia, Peru, Bolivia and Ecuador.

B. RECOMMENDATIONS TO IMPROVE THE EFFECTIVENESS AND EFFICIENCY OF THE GRAIN LEGUME PROJECT IN THE ANDREAN COUNTRIES

The Initiation Phase of PROCIANDINO (PROCIANDINO I) is for three years, starting in 1987 and ending in April 1990. The Development Phase (PROCIANDINO II) is scheduled for the next five years ending in April 1995. The Maturation Phase (PROCIANDINO III) is scheduled for the next two years, ending in April 1997. The Maturation Phase involves a gradual take over of the research and extension programs by the individual countries with PROCIANDINO retaining a coordinating role. The primary objective of this consultancy was to evaluate the progress made in PROCIANDINO I and make recommendations for the Development Phase (PROCIANDINO II). The consultant qualifies his recommendations to the extent that I could not possibly comprehend all the problems or see all the progress that had been made in these four countries during my short four week consultancy. Nevertheless, I will try my best to provide realistic and meaningful recommendations, realizing that some may be misleading and some will be conspicuous by their absence. Since the Andean areas of these countries are very similar in their crops and cropping problems, I have lumped all recommendations together rather than repeat most of them for each country.

The recommendations, including a short rationale, are as follows:

1. Upgrade all grain legume researchers at least to the Master of Science level, if the individuals are capable and interested in an advanced degree. Some researchers should also be upgraded to the Ph.D level in each country. At the present time many grain legume researchers have minimal training in

research and research methodology, yet they are asked to conduct full fledged research programs. Fortunately, most of them are doing a creditable job at the present time. Related to upgrading of the researchers is provision of a small library budget for each research station so that each researcher can order a journal or two plus several pertinent reference books each year. In addition, provision must be made to send several food legume researchers from each Andean country to the Second International Food Legume Research Conference at Cairo, Egypt in February 1991.

2. Streamline the breeding program for the self-pollinated grain legumes (pea, lentil and chickpea) by means of the F_2-derived Family Method outlined in Appendix 10. The F_3-derived Family Method is nearly as effective and efficient, provided only one or two F_3 plants are selected from each F_2 plant progeny. In an applied plant breeding program emphasis should be on the use of a simple system that is both highly efficient and effective and the F_2-derived Family Method is the simplest, quickest and most effective method available. Selection for yield must be on the basis of replicated progeny tests (Appendix 8).

3. Streamline the breeding program for the cross pollinated grain legume (faba bean) using a population improvement approach. The simplest approach is to use the Random Mating Method outlined in Appendix 9. Since faba bean has a frequency of cross pollination often exceeding 10%, it cannot be handled like a self-pollinated crop and thus individual plant selection in the F_6 to F_9 as is done in the pedigree method for self-pollinated crops will be relatively ineffective for traits of low heritability such as seed yield. Selection for seed yield can only be done successfully based on replicated progeny tests (see Appendix 8). Then remnant seed of the highest yielding progenies is used to start the next cycle of selection. In the interest of applied plant breeding and practical results, all diallel studies, pedigree selection, cross pollination studies and mass selection experiments on faba bean should be terminated immediately. Each country should select two or three of their best land races and practice population improvement as above.

4. Develop a cooperative off-season program with Saskatchewan to increase progeny of individual faba bean plants so that enough seed will be available for a replicated yield trial the next year. The growing season for faba bean in Saskatchewan is May 1 to October 1. This off-season increase will permit the three generations required for one cycle of selection to be done in two years: Year 1 - Selection within a locally adapted population for maturity and pest resistance, followed by an off-season increase of the selected plants; Year 2 - Replicated yield trial to determine highest yielding parent plants; Year 3 - Remnant seed of the highest yielding progenies are replanted to initiate the second cycle of selection. Three cycles or six years should result in a detectable increase in yield (and possibly pest resistance) using this approach on a local land race.

5. Apply low rates of phosphorus fertilizer with legume seed at planting time. Pea is fairly sensitive to seed placed phosphate and stand thinning may

occur. However, lentil, faba bean and chickpea are tolerant of seed placed phosphate fertilizer. Most soils are low in phosphate and broadcast phosphate fertilizer is rapidly complexed into a form unavailable to plants. Legumes have a high phosphate requirement and respond nicely to phosphate fertilization in soils low in plant available phosphorus. Rates of 10 to 20 kg P_2O_5 per hectare should be applied with the legume seeds first in research plots. Then, if yield increases by 15% or more, seed placed phosphate can be demonstrated in farmers' fields.

6. Apply Rhizobium legume inoculant and sticker to all legume seed at planting time. Even in areas that have grown that legume before, there is often a 10% yield increase from the use of inoculant on soils low in available soil nitrogen. However, no inoculants are available locally except for a pilot project on soybean inoculant in Colombia. Thus, efforts must be made to develop a small inoculum industry in one or more of the Andrean countries. In this way, the campesinos will be able to benefit and a small industry can be started. Incidentally, legume yields respond very well to the combination of seed placed phosphate fertilizer and inoculant treated seed. Again, inoculant could be tested in small research plots and if yield increases were 10% or higher, this practice could be demonstrated in farmers' fields.

7. Increased emphasis should be placed on pea research, demonstration and development in Bolivia and Peru. Pea is well adapted to cool humid areas and is high yielding if properly managed.

8. The cropping duration of faba bean must be reduced by harvesting the seed crop when it is physiologically mature as shown by the blackening of the lower most pods. The plants can be cut, placed upright in small piles to dry and the land freed for the next crop.

9. The pedigreed seed program must be strengthened. As the breeding programs develop, many more improved varieties will be available. These must be increased rapidly and made available to the campasinos so they can receive maximum benefits promptly. New and better seed cleaning equipment must be obtained and used. A small portable unit, such as the Mini Five-in-One rotary cleaner distributed by Carter Day Ltd., P.O. Box 486, Winnipeg MB Canada R3C 2J6, would greatly facilitate cleaning of individual farmers' production of pedigreed seed.

10 The Andean countries must develop an integrated system for long-term storage of germplasm of the native Andean plants with special emphasis on flour corn, tarwi, certain potatoes, quinoa, amaranth and others. Perhaps an exchange program with the United States Plant Introduction Service would be the best short-term approach. Then, if viability of the local collection was lost somehow, researchers could request some seeds from the duplicate backup collection in the United States. In addition, the individual Andean countries must place greater priority on collection, increase, exchange and evaluation of the local land races of crops from all of the Andean countries. Such an exchange would be mutually beneficial to all Andean countries. Long-term storage of legumes means storing them in sealed containers at -20°C and few such facilities are available in the

Andean countries. Some countries are increasing the lines in their germplasm collection every three years in order to maintain viability. This is a very expensive operation. In addition, each time an individual accession is increased, there is increased probability of mixing it, losing it or accidentally transposing the number. Also, each increase of a cross pollinated species such as faba bean will result in some intercrossing and blending of the different accessions such that the identity of individual accessions changes. Long-term storage at -20°C in sealed containers will maintain viability of most legumes for over 20 years. Thus, provision of long-term storage (uninterrupted by power failures) will greatly reduce the costs of maintaining the germplasm collections and it will help maintain integrity of the individual accessions.

11. Crop diversification and value added processing should be emphasized. Thus, the growing of grain legumes is and should be encouraged to supplement the diets and the cash returns in the potato-based and maize-based economy. Growing of different types of food legumes (shelling peas, sugar snap peas, snow peas, dry peas, green shell faba beans, dry faba beans, dry lentils, green shell chickpeas and dry chickpeas) is a further type of crop diversification. Value added processing would include shelling the seeds from the pods prior to sale (see Appendix 6 for drawings of a small mechanical pea sheller). Other types of value added processing would include splitting the dry seed of the various legume crops, or even grinding it into flour to add to soups and other cooked foods as a quick cooking, high protein component. The potential legume inoculant industry, commercial seed cleaning and increased opportunities for pedigreed seed production are additional examples of diversification of the agricultural economy.

12. Make doubly sure that there is a drainage component to all irrigation projects. Many irrigation projects have been ruined by lack of drainage resulting in a high water table and gradual salinization of much of the valuable irrigated land.

13. Place high priority on cooperation with various international programs. Thus, ICARDA coordinates international crop nurseries for lentil, chickpea, faba bean and pea. In addition, they distribute F_3 and F_4 populations of various grain legumes for selection at various testing sites, as a means of helping initiate breeding and selection programs in various countries. They also provide training for researchers in these four grain legumes. In addition, other countries have foreign aid agencies that often assist development of new and promising agricultural research and development programs (See Appendix 16).

4. IMPROVED GERMPLASM AVAILABLE. ICARDA, P.O. Box 5466, Aleppo, Syria has the world mandate among the International Agricultural Research Centers for lentil, faba bean and kabuli chickpea. As such, they distribute a series of international nurseries for each of these food legume crops each year and recently initiated a similar set of nurseries for peas. They also distribute seed of F_3 and F_4 populations of these crops by request so that a breeder can look at an array of genetic variability in the early stages of a breeding program or later if he feels there is a

need. They also supply seed of special types by request, e.g., ascochyta resistant lentil, ascochyta resistant chickpea, etc.

In addition to ICARDA, there are several food legume breeding programs in North America that can provide specific genetic and breeding lines by special request, as follows:

1. Dr. John Kraft, USDA-ARS - Pea root diseases
   Irrigated Agriculture Research and Extension Center
   Prosser, Washington 99350

2. Dr. Fred J. Muehlbauer, USDA-ARS - Pea, lentil and chickpea breeding
   Johnson Hall
   Washington State University
   Pullman, Washington 99164

3. Dr. Alfred E. Slinkard - Pea and lentil breeding
   Crop Development Centre
   University of Saskatchewan
   Saskatoon SK S7N OWO

4. Dr. S.T. Ali-Khan - Pea breeding
   Agriculture Canada Research Station
   P.O. Box 3001
   Morden MB ROG 1JO

5. Dr. Earl Gritton - Pea breeding
   Dept. of Agronomy
   University of Wisconsin
   Madison WI 53706

6. Prof. Robin A.A. Morrall - Ascochyta blight of lentil
   Dept. of Biology
   University of Saskatchewan
   Saskatoon SK S7N OWO

7. Dr. Walt Kaiser - Ascochyta blight of chickpea
   Regional Plant Introduction Station
   Johnson Hall
   Washington State University
   Pullman WA 99164

8. Dr. Sam Dietz - USDA Plant Introductions of lentil, chickpea and faba bean
   Coordinator
   Regional Plant Introduction Station
   Johnson Hall
   Pullman WA 99164

9. Coordinator - USDA Plant Introductions of peas
   Regional Plant Introduction Station
   New York Agriculture Experiment Station
   Geneva NY

10.Dr. R.O. Hampton - Pea viruses
Dept. of Botany and Plant Pathology
Oregon State University
Oregon State University
Corvallis OR 97331

1. **Summary of Recommendations Related to Genetic Improvement**

The simplest, yet very effective, method of breeding self pollinated crops such as lentil, pea and chickpea is the F_2-derived Family Method as outlined in Appendix 10 . Likewise, the simplest, yet very effective, method of breeding cross pollinating crops such as faba bean is a population improvement procedure using the Random Mating Method as outlined in Appendix 9. Since these are applied plant breeding programs and the primary objective is to quickly produce an improved variety, emphasis must be placed on selecting for yield based on replicated progeny tests (Appendix 8). This means that studies on yield components, diallel crosses and determination of levels of cross pollination should be terminated promptly and emphasis placed on selection for increased yield. Germplasm resources include local land races from throughout the Andean region, ICARDA nurseries and segregating populations and entries in the United States Department of Agriculture Plant Introduction System. These are all readily available on request. Addresses are available in the text. These collections include sources of resistance to stresses, disease resistance and possibly insect resistance. New varieties should be increased and distributed as soon as possible.

2. **Summary of Recommendations Related to Agronomic Improvement**

Production systems that involve intercropping of grain legumes and non-legumes with matching growth habits are appropriate when the crops are hand planted, hand weeded and hand harvested. Current research is helping determine the most appropriate combinations in the different areas and the best seeding dates and rates. Inoculation with the appropriate strain of Rhizobium and use of seed placed phosphate fertilizer should be evaluated in research plots and the best responses demonstrated in farmers' fields.

Grassy weeds can easily be controlled in grain legumes by herbicides such as diclofop methyl, sethoxydim and fenoxaprop-ethyl with no damage to the grain legume. Broadleaf weed control in grain legumes is not as easily done, but various herbicides have been used successfully in other areas and should be evaluated in the Andean region, e.g., trifluralin, metribuzin, bentazon and ethalfluralin. In addition, MCPA can be used for broadleaf weed control in the pea crop if sprayed before the 6th node stage. However, chemical weed control is more difficult with mixed cropping.

The best and least expensive disease control is with resistant varieties, but these are not available in many crops. Various fungicides are being used

effectively, but operator safety is being ignored in many instances. Intermediate levels of resistance may permit reductions in the number of protective sprays.

Insects are being controlled by various insecticides, but operator safety is even more critical with application of most insecticides than with application of fungicides and herbicides. Guidelines should be established on threshold populations of various insects so that compesinos would know if spraying was justified. Resistant germplasm may possibly be obtained by combining different sources of low levels of resistance in various land races, but this is a long-term project.

Small-scale mechanization should probably concentrate initially on the threshing and seed cleaning operation. Various plot size portable threshers and cleaners are available from places such as Allan Machine Co., Ames, Iowa and Bill's Welding, Pullman, Washington, but they are very expensive. They would be useful in a pedigreed seed program. New varieties must be increased, demonstrated and distributed promptly to transfer their benefits to the campesinos. Harvest and post-harvest losses can be high in areas of heavy rainfall at harvest time. Proper storage facilities are required to keep the product dry.

5. SELECTED BIBLIOGRAPHY

ICARDA and the University of Saskatchewan have a joint project to assemble all available literature on lentil and place the title, author, subject and abstract in a computerized data base. This then can be accessed by anyone in the world and they will be able to request a photocopy of the original article if available. This service should be functioning sometime in 1990.

In addition, the Commonwealth Agricultural Bureaux publishes Faba Bean Abstracts and Lentil Abstracts.

In addition, there are a series of recent publications on the grain legumes. A partial listing follows:

A. NEWSLETTERS

1. LENS
   c/o Dr. W. Erskine, ICARDA
   P.O. Box 5466
   Aleppo, Syria

2. FABIS
   c/o ICARDA
   P.O. Box 5466
   Aleppo, Syria

3. International Chickpea Newsletter
   ICRISAT
   Patancheru
   A.P. 502 324
   India

4. The Pisum Newsletter
   c/o I.C. Murfet
   Department of Plant Science
   University of Tasmania
   Hobart, Tasmania 7001
   Australia

B. REFERENCE BOOKS

1. Biddle, A.J., Knott, C.M. and Gent, G.P. 1988. The PGRO pea growing handbook. 6th ed. PGRO, Thornhaugh, Peterborough, England.

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3. Cubero, J.I. and Moreno, M.T. (ed.). 1983. Leguminosas de grano. Ediciones Mundi-Presna, Madrid, Spain.

4. Duke, J .A. 1981. Handbook of legumes of world economic importance. Plenum Press, N.Y.

5. Hawtin, G. and Webb, C. (ed.). 1981. Faba bean improvement. Martinus Nijhoff Publ., The Hague, Netherlands.

6. Hebblethwaite, P.D. (ed.). 1983. The faba bean (*Vicia faba* L.). Butterworths, London, England.

7. Hebblethwaite, P.D., Heath, M.C. and Dawkins, T.C.K. (ed.). 1985. The pea crop. Butterworths, London, England.

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11. Saxena, M.C. and Varma, S. (ed.). 1985. Faba beans, kabuli chickpeas, and lentils in the 1980s. International center for Agricultural Research in the Dry Areas, Aleppo, Syria.

12. Saxena, M.C. and Singh, K.B. (eds.). 1984. Ascochyta blight and winter sowing of chickpeas. Martinus Nijhoff Publ., The Hague, The Netherlands.

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15. Summerfield, R.J. and Roberts, E.H. (ed.). 1985. Grain legume crops. Collins, London, England.

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17. Thompson, R. (ed.). 1981. Vicia faba: Physiology and breeding. Martinus Nijhoff Publ., The Hague, The Netherlands.

18. Thompson, R. and Casey, R. (ed.). 1983. Proceedings of the symposium on perspectives for peas and lupins as protein crops. Martinus Nijhoff Publ., The Hague, The Netherlands.

19. van der Maesen, L.J.G. 1972. Cicer L., a monograph of the genus with special reference to the chickpea (Cicer arietinum L.), its ecology and cultivation. H. Veenman & Zonen, N.V., Wageningen, The Netherlands.

20. Webb, C. and Hawtin, G. 1981. Lentils. Commonwealth Agricultural Bureaux, Farnham Royal, Slough, England.

21. Westphal, E. 1974. Pulses in Ethiopia, their taxonomy and agricultural significance. Centre for Agricultural Publishing and Documentation, Wageningen, The Netherlands.

22. Williams, P., Jaby al-Haramein, F., Nakkoul, H. and Rihawi, S. 1986. Crop quality evaluation methods and guidelines: Cereals, food legumes and forages. Technical Manual 14, ICARDA, Aleppo, Syria.

23. Witcombe, J.R. and Erskine, W. (ed.). 1984. Genetic resources and their exploitation - Chickpeas, faba beans and lentils. Martinus Nijhoff/Dr. W. Junk Publ., The Hague, The Netherlands.

APPENDIX 1

Institutions Visited

A. **Colombia**

1. Centro Nacional de Investigacion, Institute Colombiano Agropecuaria (ICA), Tibaitata, Bogota.

2. Centro Regional de Investigacion, ICA, Obonuco, Pasta.

3. Substation, ICA, Ipiales.

B. **Peru**

1. Instituto Nacional de Investigacion Agraria Y, Agroindustrial (INIAA), Av. Guzman Blanco 309, Lima.

2. Estacion Experimenta Agropecuaria Andenes, INIAA, Av. Huascar No. 226A, Huanchac, Cuzco.

3. Convenio Peru Alemania Para Cultivos Andinos (COPACA), Av. Sol #817, Cuzco.

4. CANSAVE, Ayuda Para La Agricultura, Av. Los Incas No. 1510, Cuzco.

C. **Bolivia**

1. Centro de Investigaciones Fitoecogeneticas de Pairumani, Casilla 128, Cochabamba.

2. San Benito Research Station, Institute Boliviano de Tecnologia Agropecuaria (IBTA), San Benito.

3. Mision Tecnica Alemania (Gesellschaft fur Technische Zussamenarbeit (GTZ), Programa de Riego Altiplano/Valles (PRAV), Casilla No. 1503, Gitano BV, Cochabamba.

4. Departmento de Fitotecnia, Facultad de Ciencias Agricolas Y Pecuarias, Universidad Mayor de San Simon (FCAP), km 5 Carret Sta Cruz, Casilla 992, Cochabamba (Didn't actually visit the University, but gave a lecture to staff members elsewhere and discussed grain legumes with one of them).

D. **Ecuador**

1. Instituto Interamerican de Cooperacion para la Agricultura (IICA), Apartado 201-A, Mariana de Jesus 147 y La Pradera, Quito, Ecuador.

2. Programa Cooperativa de Investigacion Agricola para la Subregion Andina (PROCIANDINO), Legume Program, Apartado 201-A, Mariana de Jesus 147 y La Pradera, Quito, Ecuador.

3. Institute Nacional de Investigaciones Agropecuarias (INIAP), Avdas. Amazonas y Eloy Alfaro, Quito, Ecuador.

4. Estacion Experimentale "Santa Catalina", INIAP, Km 18, Panamericana Sur, Casilla 340, Quito, Ecuador.

5. Estacion Experimentale "Tumbaco" (INIAP), Tumbaco, Ecuador.

APPENDIX 2

Places or Regions Visited

Date	Itinerary
Feb. 25	Flew Saskatoon to Los Angeles.
Feb. 26	Flew Los Angeles to Bogota, Colombia.
Feb. 27	Spent day at Tibaitata Research Station, toured plots and received background information on crops, soils and climate.
Feb. 28	Toured commercial fields of faba bean and pea around Bogota.
Mar. 1	Presented seminar on breeding and management of grain legumes at Tibaitata and flew to Pasto.
Mar. 2	Presented seminar on breeding and management of grain legumes at Obonuco Research Station. Reviewed the faba bean breeding program with Oscar Checa.
Mar. 3.	Went to Ipiales substation and evaluated many faba bean fields along the way.
Mar. 4	Reviewed faba bean management research at the Obonuco Research Station.
Mar. 5	Returned to Bogota.
Mar. 6	Flew to Lima, Peru.
Mar. 7	Visited La Molina Research Station. Limited activity due to prolonged public service strike. Visited the National Plant Germplasm Program and discussed needs.
Mar. 8	Flew to Cuzco and drove through the Surite area to the Research Station. Evaluated the faba bean breeding and management experiments with the assistance of Roberto Horqque's technician. Evaluated the pea experiments.
Mar. 9	Visited the University of Peru-West German joint project on Andean Crops (COPACA) at Cuzco and discussed progress on the project. They have just completed the 3-year Pilot Phase with meaningful progress. They are entering the 4-year Consolidation Phase in which they transfer techniques and technology to 50 communities. Their objective is to use Andean crops plus wheat to improve the protein level in the campesino diet.
Mar. 10	Flight to Lima cancelled due to low clouds. Worked on report.
Mar. 11	Flew to Lima

Mar. 12	Flew to Cochabamba, Bolivia
Mar. 13	Visited Pairumani Research Station and toured the plots. Discussed research programs with various researchers.
Mar. 14	Presented seminar on breeding and management of grain legumes at Pairumani Research Station.
Mar. 15,16	Evaluated grain legume demonstration plots on the West German (GTZ) irrigation project with Ranier Rothe. The Punata Irrigation Project involves about 5000 ha and 3600 farm families. Visited the San Benito Research Station and saw irrigated lentil, pea, faba bean and chickpea plots. Crop diversification is an important thrust of the GTZ project. Toured the Tiraque Irrigation project and the center of faba bean production near Colomi.
Mar. 17	Presented seminar on breeding and management of grain legumes to staff and students of the Departments de Fitotecnia, Universidad Mayor de San Simon in the morning and to the GTZ project personnel in the afternoon.
Mar. 18	Flew to Lima.
Mar. 19	Flew to Quito, Ecuador.
Mar. 20	Visited Santa Catalina Research Station and reviewed faba bean, lentil, pea and chickpea research.
Mar. 21	Toured lentil and pea plots on a research site near Tumbaco. Severe infection by Rhizoctonia was noted on most pea and lentil varieties. Some moderately resistant lines were noted.
Mar. 22	Drove to lentil and chickpea plots near Salache and saw pedigreed seed fields of lentil and chickpea.
Mar. 23	Presented seminar on breeding and management of grain legumes at Santa Catalina Research Station.
Mar. 24	Background information on IICA and PROCIANDINO was reviewed with emphasis on the Grain Legumes Program and the four major projects therein.
Mar. 25	Worked on report
Mar. 26	Flew to Bogota
Mar. 27	Flew to Los Angeles
Mar. 28	Flew to Saskatoon.

APPENDIX 3

Names, Addresses and Working Responsibilities of Scientists That were Contacted

I. Centro Nacional de Investigacion, Tibaitata,

A. Instituto Colombiano Agropecuaria (ICA), A.A. 151123, Eldorado, Bogota, Colombia.

1. Dr. Alejandro Hugo Manzano, Director
2. Dr. Pedro Leon Gomez, Small-Farm Cropping Research Division Director.
3. Ing. Jaime Osorio, Horticulture Program Coordinator.
4. Ing. Gustavo Ligarreto, Bean Breeder (lentil research).
5. Ing. Fabio Higuita, Vegetable Researcher (faba bean research).
6. Ing. Jorge Velandia, Plant Pathologist (pea and faba bean research).
7. Ing. Dora Rodriguez, Plant Pathologist (faba bean research).

B. Obonuco Regional Research Station, Instituto Colombiano Agropecuaria (ICA), A.A. 339, Pasto, Colombia

1. Ing. Oscar Chea, Horticulture Program (faba bean breeding and management; testing and evaluating pea selections).
2. Ing. Omar Guerrero G., Plant Pathologist (faba bean and pea diseases).
3. Ing. Orlando Monsalve, Multiple Cropping Systems Research (faba bean and pea research plus many others).
4. Ing. Nhora Ruiz, Entomologist (faba bean amd pea research).
5. Ing. Bernardo Garcia, Soils Program.

C. Ipiales Substation, Instituto Colombiano Agropecuaria (ICA), Ipiales, Colombia - brief visit only, no conference.

II. In Peru

A. Instituto Nacional de Investigacion Agraria Y Agroindustrial (INIAA), Av. Guzman Blanco 309, Lima, Peru.

1. Angel Oviedo Aleman, Director of Research.
2. Ing. Alfredo Llona R., Advisor to the Director of Research
3. Ing. Carlos Panizo, Pathologist (dry bean research).
4. Dr. Bill Johnson, Research Coordinator.
5. Victor Merino, Human Resources Advisor.
6. Dante Castro Moreno, Director, Human Resources Unit.
7. Alfredo Matos, Soils Program.
8. Adolpho Alcantara, Director, La Molina Research Station.
9. Rufino Montalvo, Leader of the Legume Research Program and Leader of the Oilseed Research Program.
10. Eyla Valasco Urquilo, Director, Investigations on Genetic Resources Program (PRONARGEN).

B. Estacion Experimenta Agropecuaria Andenes. INIAA Av Huascar No. 226 A -

Huanchac, Cuzco, Peru.

1. Americo Negron, Protection and Investigation Program.
2. Vidal Ortiz Arriola, Leader of the Legume Program (bean breeder).
3. Roberto Horqque, Pea and Faba Bean Researcher (absent to special course in Pasto, Colombia).
4. Miriam Gamarra, Plant Pathologist (absent).
5. Dr. William Latorre Luna, Director.

C. Convenio Peru Alemania Para Cultivos Andinos (COPACA) Av. Sol #817, Cuzco, Peru.

1. Dr. Gerd Addick, Coordinator.
2. Ing. Jorge A. Tang Chang, Coordinator.

D. CANSAVE, Ayuda Para La Agricultura, Av Los Incas No. 1510, Cuzco, Peru. I spoke with the secretaries about the program as everyone was out in the field.

III. In Bolivia

A. Centro de Investigaciones Fitoecogeneticas de Pairumani, Casilla 128, Cochabomba, Bolivia

1. Dr. Gonzalo Avila, Director.
2. Luis Pierola, Durum Wheat Breeder.
3. Mario Crespa, Faba Bean Breeder - missed him as he was at a legume meeting in Pasto, Colombia.
4. Jaime Argote, Maize Breeder.
5. Raul Rios, Bean Breeder - missed him as he is working on his M.Science in Mexico.

B. San Benito Research Station, Instituto Boliviano de Tecnologia Agropecuario (IBTA), San Benito, Bolivia.

1. Jaimie Salamanca, Director

C. Mision Tecnica Alemania (Gesellschaft fur Technische Zusammenarbeit (GTZ), Programa de Riego Altiplano/Valles (PRAV), Casilla No. 1503, Gitano BV, Cochabamba, Bolivia.

1. Ranier Rothe, Agronomo Especialista en Riego, Asesor Apropecuario (Irrigation Specialist).
2. Rudy Torres, Chickpea and Lentil Researcher.
3. Edith Ruiz, Bean Researcher.
4. Raul Corzo, Extension Specialist in Seed Production.
5. Antonio Montano Pena, Extension Specialist in Irrigated Crops
NOTE: Torres, Ruiz and Montano are researching grain legumes for their thesis.

D. Departmento de Fitotecnia, Facultad de Ciencias Agricolas Y Pecuarias,

Universidad Mayor de San Simon, FCAP, km 5 Carrel Sta. Criz Casella 992
Cochabamba, Bolivia.

1. Juan Herbas, Balderrama, Plant Physiologist. (Over 10 staff and students attended my seminar).

IV. In Peru

A. Instituto Interamericano de Cooperacion para la Agricultura (IICA) - Programa Cooperativa de Investigacion Agricola para la Subregion Andina (PROCIANDINO), Apdo. 201-A, Mariana de Jesus 147 y La Pradera, Quito, Ecuador.

1. Dr. G. Hernandez-Bravo, Coordinator, Internacional Leguminosas de Grano

2. B. Ramakrishna, Especialista Internacional en Transferencia de Tecnologia y Comunicacion.

3. Baltazar Quizpe, Faba Bean Breeder, from Jiron Capitan Morante #145, Puno, Peru.

4. Nelson Rivas, Director, PROCIANDINO

B. Instituto Nacional de Investigaciones Agropecuarias (INIAP), Avdas. Amazonas y Eloy Alfaro, Quito, Ecuador

1. Dr. Fabian Alvarado Espinosa, Coordinator Convenio, INIAP/PROCIANDINO

C. Estacion Experimentale "Sta Catalina", INIAP, Km 18, Panamericana Sur, Casilla 340, Quito, Ecuador

1. Jose Acuna, National Legume Coordinator and PROCIANDINO Coordinator for Lentil.
2. Edmundo Cevallos, Coordinator of Grain Legume Breeding.
3. Jose Vasquez, Head of Germplasm Bank.
4. Jose Pinzon, Grain Legume Agronomist, in charge of off-station variety testing.
5. C. Danilo Sanchez, Ch. Director.
6. Ligia Ayala, Pathologist (on grain legumes).

APPENDIX 4

GENERAL BACKGROUND ON FABA BEAN, PEA, LENTIL AND CHICKPEA

Faba bean (*Vicia faba*), pea (*Pisum sativum*), lentil (*Lens culinaris*) and chickpea (*Cicer arietinum*) are cool season annual food legumes. They are widely grown in many parts of the world as spring annuals in cool temperate areas, and as winter annuals in areas with a Mediterranean type climate, as well as at higher elevations in the Tropics such as in the Andes Mountains.

These four food legumes can be arranged in order of increasing drought tolerance: faba bean, pea, lentil and chickpea. Thus, faba bean has poor drought tolerance, pea has limited drought tolerance, while lentil and chickpea have fairly good drought tolerance. The major difference in response to drought between lentil and chickpea is that lentil has a shallow root system while chickpea has a deep root system allowing it to grow on subsoil moisture reserves, if present. None of these four legumes can tolerate poorly drained water-logged soils and chickpea is the most intolerant, often rapidly succumbing to one of the root rots if in the presence of free water for a brief period of time.

These four food legumes are high in protein, with faba bean averaging about 3 to 5 percentage points above the others (Tables A1, A2). Selected nutrient composition is presented in Table A1. The percent essential amino acids is presented in Table A2. Legume proteins are characteristically low in the sulfur-containing amino acids methionine and cystine, relative to cereal proteins. However, legume proteins are high in lysine relative to cereal proteins. Accordingly, the amino acid balance is greatly improved in a diet consisting of a blend of legume proteins plus cereal proteins, relative to cereal protein alone. Likewise, legumes increase the protein level of potato-based diets.

Table A1. Selected nutrient composition of faba bean, pea, lentil and chickpea (composition per 100 g edible portion of dried mature whole seeds).

Item	Faba bean	Pea	Lentil	Chickpea
Protein (g)	25.0	22.2	20.2	19.4
Oil (g)	1.2	1.4	0.6	5.6
Crude fibre (g)	5.1	6.0	-	2.5
Dietary fibre (g)	-	16.7	11.7	25.6
Starch (%)	51.6	54.1	59.1	54.9
Sugars (%)	5.0	8.1	6.1	13.1
Iron (mg)	4.2	4.4	7.0	2.2
Thiamin (mg)	0.45	0.77	0.46	0.46
Riboflavin (mg)	0.19	0.18	0.33	0.20
Niacin (mg)	2.4	3.1	1.3	1.2
Energy (kCal)	328	330	340	362
Calcium (%)	0.09	0.11	-	0.25
Phosphorus (%)	0.54	0.42	-	0.26

Table A2. Percentage protein (dry-matter) and percentage essential amino acid composition of that protein in faba bean, pea, lentil and chickpea.

Item	Faba bean	Pea	Lentil	Chickpea
Protein	29.0	25.7	23.0	21.8
Isoleucine	4.0	4.3	4.3	4.4
Leucine	7.1	6.8	7.6	7.5
Lysine	6.5	7.5	7.2	6.8
Methionine	0.7	0.9	0.8	1.0
Cystine	0.8	1.1	0.9	1.2
Phenylalanine	4.3	4.6	5.2	5.7
Tyrosine	3.2	2.7	3.3	2.9
Threonine	3.4	4.1	4.0	3.8
Valine	4.4	4.7	5.0	4.5

Many legumes contain alkaloids, tannins and other deleterious compounds. However, pea, lentil and chickpea are nearly devoid of such substances. Tannins or tannin precursors are found at low levels in the seed coats of pea, lentil and the dark seed coat types of chickpea, but at higher levels in faba bean. Low levels of tannins result in a slightly bitter taste and some people feel that this improves the flavor.

Faba bean contains vicine (0.44 to 0.82%, mean of 0.66%) and convicine (0.13 to 0.64%; mean of 0.25%) which have been implicated in the sex-linked disease favism which results in hemolytic anemia in people carrying a specific genetic deficiency. People who have the Mediterranean type of glucose 6-phosphate dehydrogenase (type 1) deficiency and consume faba bean often suffer severe hemolytic anemia and may require a blood transfusion rather quickly. Many deaths have been reported from this disease. The frequence of the gene for this disease is low, but is most common in people of Mediterranean origin.

A report that highly acid extracts of faba bean are mutagenic to bacteria has somehow been extrapolated to the above normal rate of gastric cancer in some parts of the Andes where there is a high consumption of faba bean. However, many compounds are mutagenic to bacteria, e.g., caffeine in coffee, and there is no direct evidence that consumption of faba bean causes gastric cancer. There may be after causes of this gastric cancer such as careless handling of pesticides.

Faba bean seed is fairly high in tannins which are concentrated in the seed coat. Faba bean breeders have found that zero or near zero tannin lines of faba bean have white seed coats and pure white flowers. Accordingly, some faba bean breeders are selecting for zero tannin faba bean lines in this manner without expensive and time-consuming chemical tests. Tannins impart a slightly bitter taste desired by some, but they also reduce protein digestibility.

Canada and the United States are major exporters of pea and lentil and

considerable quantities are exported to the Andean countries. Colombia and Venezuela are the major Andean countries. Colombia and Venezuela are the major Andean importers of Canadian pea and lentil (Table 3A). Even larger volumes are imported from the United States in most years.

Table A3. Exports of pea and lentil from Canada to the Andean countries, 1983-1987.

Lentils	1983	1984	1985	1986	1987
Colombia	15,361*	5,293	850	12,367	34,180
Bolivia	-	-	-	-	-
Ecuador	568	759	-	-	89
Peru	1,856	570	110	1,054	2,722
Venezuela	2,176	6,341	6,102	6,653	6,048
Total	19,961	12,963	7,062	20,074	43,039

Peas	1983	1984	1985	1986	1987
Colombia	5,446	501	-	3,504	13,095
Bolivia	-	-	18	-	-
Ecuador	-	-	-	-	-
Peru	-	588	18	-	18
Venezuela	16,729	12,941	21,159	5,341	5,677
Total	22,175	14,030	21,195	8,845	18,790

*Tonnes

APPENDIX 5

Benefits of Inoculating Grain Legume Seeds with Nitrogen-Fixing Bacteria (Rhizobium)

Under average levels of available soil nitrogen, symbiotic nitrogen fixation by Rhizobium will supply 30 to 40% of the nitrogen needed by an average crop of pea (Pisum sativum) or lentil (Lens culinaris) and about 70% of the nitrogen needed by an average crop of faba bean (Vicia faba), TARW1 (Lupinus mutabilis) or chickpea (Cicer arietinum). The remaining nitrogen requirement must be supplied by the soil or fertilizer nitrogen. Under low levels of available soil nitrogen, these percentages will be considerably higher, but yields will be low, unless some fertilizer nitrogen (20 to 30 kg N/ha) is applied.

However, under high levels of available soil nitrogen, the percent nitrogen in the crop that is derived from symbiotic nitrogen fixation will be low. This is because nitrogen fixation requires the expenditure of energy by the plant and under these conditions the plant will preferentially use the readily available soil nitrogen since less energy is required. Thus, maximum benefits from symbiotic nitrogen fixation occur in fields that have low to medium levels of available soil nitrogen such as after a high yielding cereal crop (wheat, barley, oat or maize).

These symbiotic nitrogen-fixing bacteria (Rhizobium) will survive in the soil for several years. Thus, if properly nodulated faba bean plants were grown in a field a few years previously, there should be an adequate number of the proper strain of Rhizobium in the soil to assure a high level of nodulation and nitrogen fixation in the next crop of faba bean. However, this strain of Rhizobium would be specific to faba bean and would not produce very many nodules in a different grain legume crop such as pea, lentil or Phaseolus bean.

The Rhizobium population in the soil consists of many different genotypes, many of which fix low levels of nitrogen and some are even parasitic and depend on the plant for their nitrogen and other nutrients. In addition, the individual bacteria are scattered throughout the soil and infect the root hairs only after the root grows next to them. This results in delayed nodulation and reduced nitrogen fixation.

Bacteriologists report that grain legumes require about 100,000 bacteria per seed for early and fully effective nodulation and high levels of nitrogen fixation on each plant. Recent studies have also shown a measurable increase in nitrogen fixation when double the recommended rate of inoculum was applied to the seed.

An additional benefit of seed inoculation is that the grower is assured of a large number of Rhizobium immediately around the seed so that infection, nodule formation and nitrogen fixation will be promptly initiated. Early initiation of nitrogen fixation is important since in Phaseolus bean, pea and lentil the rate of nitrogen fixation drops very rapidly as soon as the first pod is formed. This is because both nitrogen fixation and seed formation require photosynthetic energy and the developing pods and seeds are closer to the photosynthetic areas and are a stronger sink than are the nodules.

Rhizobium inoculum has traditionally been applied to legume seed using water, preferably with some sort of sticker such as gum arabic, sugar solution, dilute glue (paste) solution or anything sticky. The objective is to make sure a very large number of Rhizobium is tightly stuck to each and every legume seed. This is a messy and awkward procedure and even the best farmers apply Rhizobium reluctantly. Then the seed must be planted immediately after inoculation as prolonged exposure to sunlight and drying will result in death of Rhizobium.

However, science has come to the rescue of the farmer. A dry sticker has been patented and will be available in limited quantities in 1989. It is mixed with the Rhizobium inoculum and sealed in the package. Then the dry contents of the inoculum package are mixed with the dry seed and the seed is planted immediately. This new technology will greatly simplify inoculation of grain legume seed with Rhizobium for improved levels of nitrogen fixation.

In summary, inoculation of grain legumes with nitrogen-fixing Rhizobium has the following advantages:

1. Assurance of an adequate number of the right strain of highly effective nitrogen-fixing bacteria in the right place at the right time.

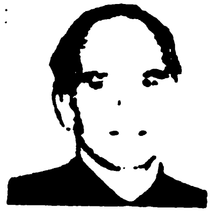
2. Early onset of nitrogen fixation.

3. The mess and inconvenience associated with use of a wet sticker has been replaced by a simpler procedure using a dry sticker.

4. Many naturally infected fields do not have 100% inoculated plants and use of inoculum often will result in yield increase of 10%

Shop Tools

By WALTER R. HOFFMANN
Program Head, Machinists Section,
Northern Alberta Institute of Technology



How to build a pea sheller

The time spent for shelling green or dry peas can be greatly reduced with a hand-operated pea sheller described in this article. We built one of these shellers last Spring and found it useful. We had a relatively large pea harvest.

The pea sheller shown here has several modifications from a design made available by Alberta Agriculture on Plan 735-1 and credit for the basic implement should go to them.

The sheller shown here is constructed of wood and metal parts and building one is not difficult. Useful tools for this project include a table saw, welder, drill press, lathe and common hand tools. However, if the above machines are not available then the plan from Alberta Agriculture should perhaps be used because it requires only hand tools and purchased parts.

For this project we suggest the purchase of part 2, 3, 14, 19, 20, 23, and 27, 28.

Construction Information

1. Rail Bearing (Part 4)
   - Drill 11/16 dia. hole through 1 Dia. round pieces, face both ends and debur.
   - Weld round collar to flat bar, then drill and file elongated holes as shown in Figure One.
   - Machine bushings (Part 6) with 1/2 dia. hole and outside dia. for press fit in to 11/16 dia. hole of rail bearing.
   - Drill 1/8 dia. oil hole through collar and brass bushing.

2. Machine Spacer (Part 5) as shown in Figure Two.

3. Crank (Part 7)
   - Machine handle as shown in Figure Three.
   - Machine sleeve as shown in Figure Four.
   - Drill and tap bar as shown in Figure Five
   - Cut slot for screwdriver in to head of capscrew and file off corners of hex.
   - Weld sleeve to bar and assemble crank as shown in Figure Six.

9. Assemble Housing (See Figure Sixteen)
   - Use woodscrew to fasten sides to rails. (Part 16).
   - Fasten stabilizer (Part 26) to rails.
   - Fasten base pieces (Part 17) to under side of rails - they will hold drawer in place.
   - Fasten support pieces. (Part 28)
   - Install hinges (Part 23) on support pieces to hinge swing door.
   - Cut cover (Part 22) plywood as follows: Two pieces each of 6 and 10 as well as one piece each of 4 and 8 wide needed; all pieces 20 1/2 long.
   - Staple screen (part 27) on to swing door.
   - Nail or staple cover pieces on to sides.
   - Remove 1/4 plywood strips to permit opening of swing door.
   - Install swing door pull or handle.

10. Build Drawer (See Figure Seventeen)

11. Final Assembly (See Figure Eighteen)
    - Push flange bushings (Part 15) in to sides.
    - Place drum in to housing; this may require removal of one or

4. Paddle Assembly
- Weld paddle plates (Part 10) to paddle shaft (Part 9) as shown in Figure Seven.
- Prepare paddles (Part 3) as shown in Figure Eight.
- Push paddles on to paddle plates and drill two 3/16 holes through each paddle and paddle plate. Fasten paddles with machine screws (10 - 32 screws and nuts).

5. Machine Flange (Parts 11 & 12)
- Machine short flange as shown in Figure Ten.

6. Machine Flanges Bushings (Part 15)
- As shown in Figure Eleven.

7. Build Drum (Part 18)
- Tack 2 pieces of 16 x 16 x 1/2 plywood together, layout, cut circle, notches and drill center hole as shown in Figure Twelve.
- Cut cross piece (Part 24) in to 19 inches lengths.
- Cut drum discs at the line shown in Figure Twelve.
- Separate discs, glue 8 pieces in to discs and install clips (Part 19) as shown in Figure Thirteen.
- Staple mesh (Part 20) around drum frame and cut mesh at opening to permit removal of drum opening.
- Install flanges (Parts 11 & 12) to drum as shown in Figure Fourteen.

8. Cut Sides (Part 21)
- Tack 2 pieces of 3/4 plywood together, layout shape, drill center hole and saw to shape as shown in Figure Fifteen.
- Cut sides while tacked together at the cutline. Small pieces will become swing door.
- Separate sides and use 1/4 plywood strips to tack swing door pieces back on to sides.

both flanges, drum should rotate freely between sides without much end play.
- Place paddle assembly in to drum and slide axle (Part 8) through housing, drum and paddle assembly. Center shaft on housing and drill a 1/8 hole through axle at middle of paddle. Use cotter pin to secure paddle assembly to axle. Paddle should rotate freely in drum without much end play. Please Note: If end play of drum and/or paddle is excessive then washers or spacers should be used to correct it.
- Mount one large pulley (Part 3) and one small pulley (Part 2) on axle.
- Place V-belts (Part 14) on pulleys.
- Assemble rail bearings (Part 4) with crankshaft, spacer (Part 5) and remaining small and large pulleys.
- Place this assembly on to stabilizer with V-Belts on pulleys. Pull assembly to tighten V-Belts and mark location of rail bearings.
- Drill stabilizer, fasten rail bearings, tighten V-Belts, align crankshaft pulleys with axle pulleys, install crank and pea sheller should be ready for use.

A Final Note

Best results were achieved when removing peas from drawer several times while shelling peas because towards the end of the shelling process small pieces of pods often fall in to the drawer which then will require some work in separating peas from pod pieces. A load of about 6 quarts (6.8 litres) is recommended per load and a speed of about 120 turns per min, of the crank seems best. Excessive amounts of pods will drop if one turns longer than one minute.

Figure One

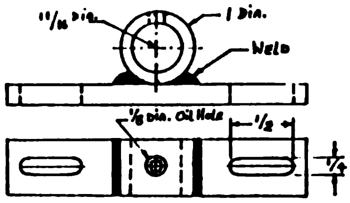


Figure Two

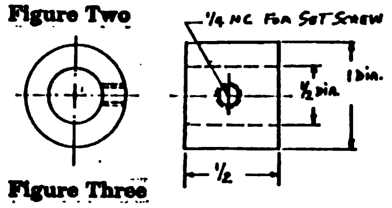


Figure Three

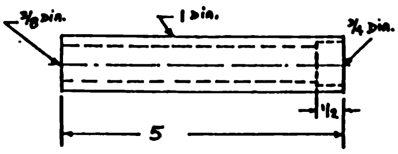


Figure Four

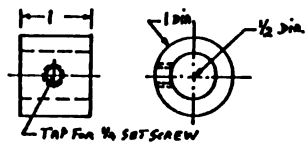


Figure Five

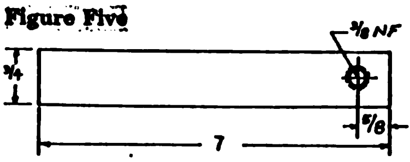


Figure Six

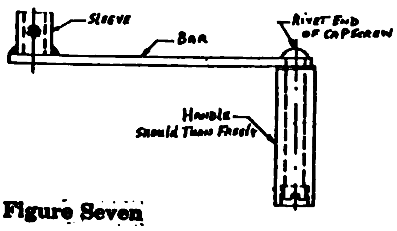


Figure Seven

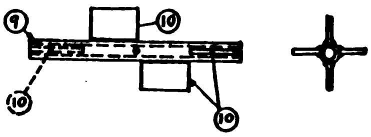


Figure Eight

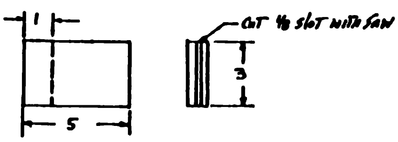
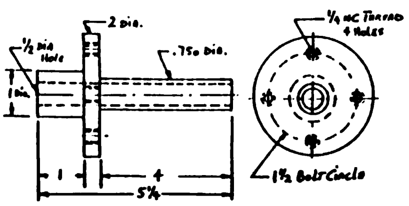


Figure Eight

Figure Nine



FINISHED PEA SHEI IER

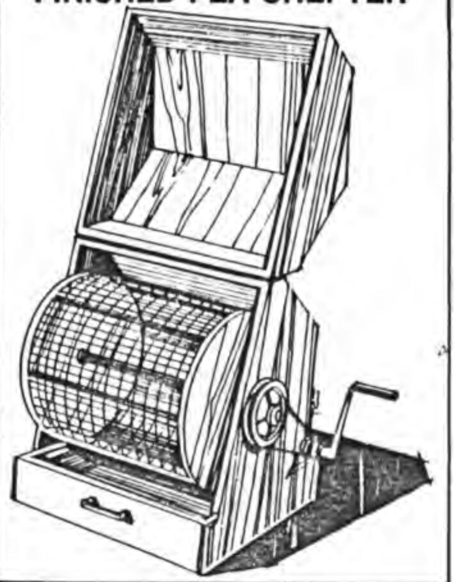


Figure Ten

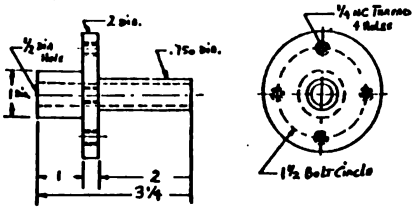


Figure Eleven

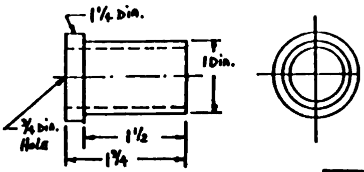


Figure Twelve

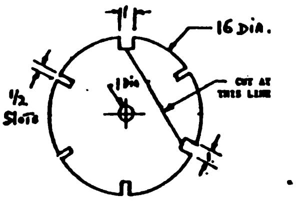


Figure Thirteen

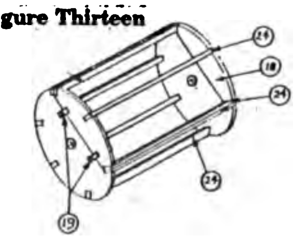


Figure Fourteen

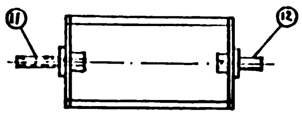


Figure Fifteen

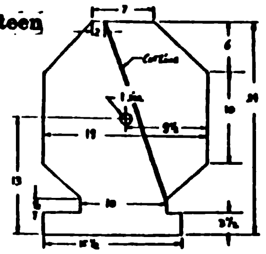


Figure Sixteen

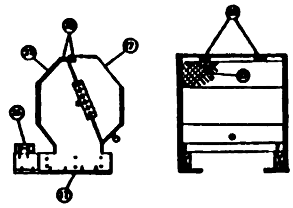


Figure Seventeen

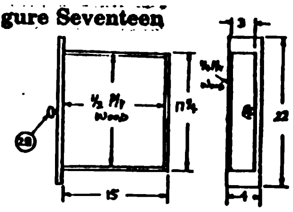
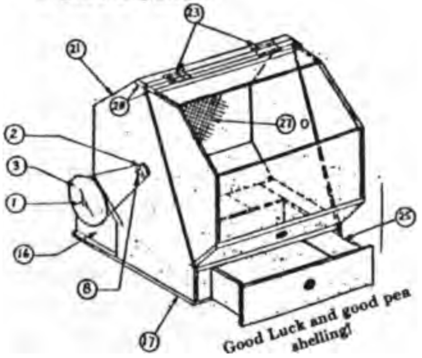


Figure Eighteen



Good Luck and good pea shelling!

Parts List (All dimensions in inches)

Part No.	Name	No. Req.	Specifications
1	Crankshaft	1	1/2 dia. x 25 long, steel
2	Small "V" pulley	2	2 dia. aluminum, 1/2 dia. holes
3	Large "V" pulley	2	6 dia. aluminum, 1/2 & 3/4 dia. holes
4	Rail bearing	2	1/4 x 1 x 5 long, 1 dia. x long, steel
5	Spacer	2	1 dia. x 1/2 long steel
6	Bushing	2	3/4 dia. x 1 long, brass
7	Crank	1	1/4 x 3/4 x 7 long, 1 dia. x 1 long; 1 dia. x 5 long; capscrew 3/8NF x 5 long
8	Axle	1	1/2 dia. x 26 long, steel
9	Paddle shaft	1	1/2 pipe x 16 long, steel
10	Paddle plate	4	1/8 x 1 x 3 long, steel
11	Long flange	1	2 dia. 5 1/4 long, steel
12	Short flange	1	2 dia. x 3 1/4 long, steel
13	Paddle	4	3 x 5 x 1/2 thick wood
14	V-Belt	2	3L380 Mastercraft or equivalent
15	Flange bushing	2	1 1/4 dia. x 1 3/4 long, brass
16	Rail	2	2 x 4 x 19 long, wood
17	Base	2	1/2 plywood, 8 x 19 long
18	Drum	1	1/2 plywood, 16 x 32
19	Clip	4	Suitcase catches
20	Mesh	1	1/2 x 1/2 mesh, 18 x 50 piece
21	Side	2	3/4 plywood, 24 x 20
22	Cover	1	1/4 plywood, 21 x 44
23	Hinge	2	4 long piano hinges
24	Cross piece	1	1/2 x 1 x 144 long wood
25	Drawer	1	10 x 22 x 1/2 & 15 x 18 x 1/4 plywood
26	Stabilizer	1	2 x 6 x 20 1/2 long wood
27	Screen	1	10 x 22 screen door mesh
28	Support	2	3/4 x 2 x 19 long, wood
29	Hardware		Woodscrews, setscrews, drawer pull knob, machine screws, nuts, washers, swing door handle, cotter pins

APPENDIX 7

Special Considerations in Breeding Grain Legumes

Grain legume crops differ from cereal crops in several respects. The effect of these differences is to reduce the effectiveness of standard breeding techniques and to emphasize the use of modified breeding techniques which are more effective and more efficient than the standard breeding techniques.

The major difference is that cereals have a determinate growth habit, while most grain legumes have an indeterminate growth habit, that is, they often have nearly ripe pods and open flowers on the same plant. Plants with an indeterminate growth habit are able to respond to a timely rain anytime during pod formation. Thus, a slight difference among varieties in maturity, or expression of the indeterminate growth habit, will result in differential response to the rain, that is, one variety will respond to a greater degree than another. This contributes to the genotype by environment interaction and is only evident when a set of varieties (genotypes) is tested over a range of environments or test sites. This means that one variety will be best at one site, while another variety is best at another site. The net effect of a high genotype by environment interaction is that many more yield trials must be conducted to select the variety that is clearly the best overall site. In addition, the data may indicate that some of the environments are so different that a second variety should be selected for a subset of the environments.

A second major difference between cereals and grain legumes is the "seed increase ratio". This refers to the average number of seeds produced by one plant and is largely a function of seed size. Thus, grain legumes are characterized by large seeds and usually have a seed increase ratio between 10 and 30, that is, one plant will produce between 10 and 30 seeds under average conditions. Wheat has a seed increase ratio of between 50 and 150, while canola (Brassica napus) has a seed increase ratio of between 200 and 500 under average conditions. Thus, grain legumes present special problems in that single plant selections must be increased at least one generation and often two generations before there is enough seed available for a replicated yield trial at one location. Selection for yield requires replicated testing at least at one site and preferably at a minimum of two sites. Thus, selection for yield in grain legumes must be delayed one more years longer after the initial selection than is the case in cereals. This emphasizes the importance of using a modified breeding technique to compensate for this disadvantage.

A third major difference between grain legumes and cereals is that grain legumes can fix nitrogen symbiotically in association with Rhizobium, while cereals cannot. Nitrogen fixation requires energy from recently produced photosynthates which is translocated to the nodules on the roots. This means that the plant will have a reduced yield relative to a nonfixing plant under the same level of nitrogen nutrition. Thus, nitrogen fixation may reduce yield potential of a given variety, even though it will increase actual yield under low to medium levels of nitrogen nutrition.

A fourth major difference is that grain legumes have a much higher protein concentration than the cereals. For example, many grain legumes have a grain protein concentration of 210 to 250 g/kg (21 to 25%), while most cereals range

from 90 to 130 g/kg (9 to 13%). Plants require more energy to produce one gram of protein than one gram of carbohydrate. Thus, the yield of high protein grain legumes will rarely, if ever, equal that of low protein cereals. The net result is that there will never be a yield breakthrough in grain legumes like that in the semidwarf wheat, semidwarf rice and hybrid corn. This means that increased yield will be harder to attain in new varieties of grain legumes than in new varieties of cereals and emphasizes the importance of the use of more effective and more efficient plant breeding methods in the grain legumes.

In summary, grain legume improvement is more difficult than cereal improvement and more efficient and effective breeding methods are required because of 1) their indeterminate growth habit resulting in a high genotype by environment interaction, 2) their low seed increase ratio resulting in an extra generation of seed increase before yield testing can be done, 3) the high energy requirement for nitrogen fixation resulting in reduced yield potential, and 4) the high energy requirement for production of protein in these high protein crops, further reducing yield potential.

APPENDIX 8

Principles of Breeding for Yield from a Practical Applied Viewpoint

One of the major objectives of every plant breeding program is increased yield. It is also one of the more difficult objectives to achieve, primarily because yield is a trait of low heritability. Highly heritable traits such as maturity, plant height or seed weight can be selected successfully on an individual plant basis. However, the only successful way to select for a trait of low heritability, such as yield, is to use replicated progeny tests. A progeny test provides a measure of the genetic composition of the parent plant which helps the plant breeder select the genetically superior plants.

The simplest approach for self pollinated crops such as pea, lentil and chickpea is to assume that yield is conditioned by many genes with small additive effects. Thus, the objective of breeding for yield is to accumulate an ever increasing number of these genes in a series of new varieties. This is most effectively done by crossing one high yielding variety with a second high yielding variety carrying different genes for yield and then selecting successfully for higher yield in the segregating progeny, based on replicated progeny tests.

However, a problem arises when a desirable trait such as shorter plant height is found in a low yielding, poorly adapted line. If this line was crossed directly with an adapted variety, the average number of genes for yield would be reduced and the average yield of the segregating generations of this cross would be low, making it difficult to recover a selection that yielded as high as the adapted variety. A preferred approach is to cross the poorly adapted line carrying the desired trait to a high yielding parent, backcross the F_1 to the adapted parent, select for high yield and the desired trait in the F_3 (pre-adaptation) and then cross these selected plants to a second adapted variety. In this way a desired trait can be introduced into the breeding program without sacrificing much yield.

The universal negative relationship between yield and protein concentration strongly suggests that the plant breeder should not select for both high protein and high yield. The one major exception to this was found with Atlas 66 wheat. The preferred approach is to select for increased yield, while holding protein concentration constant. Producers are normally paid for yield and any premium for higher protein concentration rarely will compensate for the associated reduction in yield.

It is generally more efficient to select for yield directly rather than trying to select for yield based on yield components, since there is a high level of component compensation among yield components, that is, selection for one yield component will usually result in a reduction in one or more of other yield components. There are two major exceptions to this generalization. The first exception is when two complementary traits such as oil and protein are negatively correlated with each other and with yield. In this case the plant breeder can successfully select for oil or protein holding yield constant, or select for yield holding protein and oil constant or use a selection index to select for increased oil and protein holding yield constant. A second exception occurs when two highly heritable components are positively correlated with yield, but negatively correlated with each other. Such a case

occurs in cross pollinated grasses where percent fertile florets and seed weight are positively correlated with seed yield, but negatively correlated with each other. In this case a selection index involving the two components (percent fertile florets and seed weight) was very effective in increasing seed yield. However, in general it is more efficient to select for yield directly, based on replicated progeny tests, and not waste time and money studying and selecting yield components.

It is imperative that a specific objective such as yield and/or disease resistance be maintained during the course of the breeding program so that the objective can be attained. This also implies that the plant breeder be assigned to this project on a long term basis. Whenever a new plant breeder is assigned to an ongoing breeding program, several years are lost while the material is re-evaluated and often the objective and the approach are changed. Whenever there is a major change in objective, it is as if the breeding program was starting from scratch again, a very inefficient approach. If a new objective is necessary, a subsample of the improved breeding material should be used as the starting material and the original objective maintained with the improved breeding material if this objective is still pertinent. The new objective can be started with the subsample using the first backcross approach as outlined earlier.

Direct selection for yield also has the potential to indirectly accumulate genes with small additive effects for resistance to endemic diseases, provided such genetic variation is present in the improved germplasm. This may result in tolerance to the disease such that the new variety yields well even though infected by the disease.

In summary, the simplest and most practical approach to breeding for increased yield is to select directly for yield in replicated yield trials. The basic assumption in this approach is that yield is conditioned by many genes with small additive effects. Additional genetic variation can be added to the improved breeding material by making a cross and a backcross to an adapted high yielding variety, and selecting for the desired trait and yield in the F_3 before crossing this genetic variation to the improved genetic material. This will minimize any reduction in yield of the improved genetic material. The negative correlation between yield and protein concentration and the lack of an adequate premium for high protein suggests that selection be for increased yield holding protein concentration constant. It is also more efficient to select for yield directly rather than to select for yield components due to component compensation. The plant breeder also must maintain a primary objective (higher yield) during the duration of a given breeding program with a given set of improved genetic materials. Again, it must be emphasized that selection for yield can only be successful, if based on a replicated progeny test.

APPENDIX 9

Outline of a Plant Breeding Program for an Often Cross Pollinated Annual Crop Such as Faba Bean

A plant breeding program for an often cross pollinated crop traditionally develops through a typical sequence of events characterized by 1) Introduction, 2) Mass Selection (various modifications) within the best introductions, and 3) Population Improvement using various recurrent selection schemes.

Introductions may consist of local varieties (land races) and varieties or populations from other parts of the world. These introductions are evaluated in replicated yield trials in the area of production and the best one may be selected as the first variety.

Mass Selection or some modification such as Maternal Line Selection within the best introductions will be effective for highly heritable traits such as plant height, maturity, seed weight or major gene disease resistance and can result in an improved variety. However, mass selection techniques are not very effective in increasing traits of low heritability like yield and thus more effective methods are required.

A Population Improvement scheme involving some form of recurrent selection is the preferred method of breeding for yield in an often cross pollinated annual crop such as faba bean. The primary restriction is that all selections must be evaluated for yield in a replicated yield trial and only a sample of the highest yielding progenies is included in the next cycle of selection. The starting population is the best available one as determined by testing of introductions and/or mass selection.

Theoretically, the most effective method of Population Improvement is the Diallel Cross Method, which involves making all possible intercrosses among progenies that have been selected for high yield in the replicated yield trial. However, in practice this is not workable for faba bean since the high yielding progenies are not known until the yield trial has been conducted and they would have to be grown again the next generation to make the crosses, further lengthening the selection cycle.

Recently, a simple, effective and highly efficient selection method has been developed specifically for faba bean. It is known as the Random Mating Method. It is nearly as effective as the Diallel Cross Method, provided the level of cross pollination is greater than 5%, and is much easier, more efficient and quicker (see below).

The Random Mating Method of Population Improvement for Faba Bean

Generation	Procedure
1	Cycle 1 is started with the best available population (variety). Five hundred spaced plants are grown and the best 100 are selected, based on highly heritable traits such as height, maturity, seed weight, seed color and disease resistance (if clear differences are present).
2	The 100 selected plants are grown in plant rows to increase seed for a replicated yield trial.
3	The 100 plant progenies are grown in replicated yield trials and the 20 highest yielding progenies are selected to start the next cycle.
4	Cycle 2 is started with remnant seed of the increase (25 seeds from each of the 20 highest yielding progenies). The seed is mixed and space planted.

Each selection cycle takes 3 generations or 3 years if only one generation is grown per year. However, it is feasible to grow the increase generation (generation 2,5,8, etc.) outside the area of adaptation and reduce this to 2 years per cycle. For example, the increase generation could be grown at the University of Saskatchewan between May 1 and October 1 and speed up the process. It should be possible to develop an improved variety after 2 cycles (4 years) using this method and an even better one after 4 cycles (8 years).

The above approach is limited to exploiting the genetic variability present in the original population. Often it is desirable to add additional genetic variability for yield, disease resistance or some highly heritable trait to the breeding population. This additional source of genetic variation may be poorly adapted and low yielding. If this is so, special precautions must be taken to make sure that the yield gains are not lost in the process. The most appropriate approach is illustrated as follows: Assume that the additional desired trait is green colored seed. Then the source of the green colored seed is crossed to a sample of the improved population and this F_1 is backcrossed to a sample of the improved population. The resulting BCF_1 is grown as spaced plants (100 or so) and those plants with green seeds are increased as plant rows in the BCF_2. These plant rows are again selected for green seeds and each selected plant row is grown in a replicated yield trial in the BCF_3. The highest yielding 10% of these plant rows will be fairly well adapted and can be included as part of the population to start the next cycle of selection. The only restriction is that this additional source of genetic variation should constitute less than 15% of the population (75 plants out of 500) for the next cycle of selection. In this way additional genetic variation can be added to the selected population without any serious effect on yield. Again the increase generation can be grown outside the area of adaptation to speed up the process. This approach with strong emphasis on selection for yield in replicated yield trials also has the potential to inadvertently select for disease or insect tolerance, that is, the ability of the plant to yield well even though it is infected or infested with the disease or insect. This is an important aspect in those cases where a higher

level of resistance is not available or is not evident.
In summary, a plant breeding program in an often cross pollinated crop such as faba bean starts with 1) Introductions, 2) Mass Selection and 3) Population Improvement using various recurrent selection schemes. A recently developed recurrent selection scheme, the Random Mating Method, is presented in detail. It is simpler, quicker and more efficient than most standard methods of recurrent selection. A procedure for adding additional genetic variation to the improved breeding population without sacrificing yield is presented in detail. Emphasis is placed on the use of replicated yield trials to select for yield. An increase generation is required to produce enough seed for a replicated yield trial and it is proposed that this be grown at the University of Saskatchewan between May 1 and October 1 so as to get two generations per year and speed up the plant breeding program.

The effectiveness of selection for yield can be increased if remnant seed of the cycle 1 plants that produced the highest yielding progenies is used to start cycle 2. The major consideration then is that the number of remnant seed x the number of high yielding selections must equal the original population size (500 in the example used). Thus, if there are 10 remnant seed, then the parents of the top 50 yielding progenies must be used to reconstitute the population. With large seeded faba beans, it may be difficult to save a remnant of 10 seeds and get a large enough increase from the rest of the plant for a replicated yield trial the next year and thus the Random Mating Method may well be the method of choice.

APPENDIX 10

Outline of a Plant Breeding Program for a Self-Pollinated Crop

A plant breeding program for a self-pollinated crop traditionally develops through a typical sequence of events characterized by 1) Introduction, 2) Selection within the best introductions, and 3) Hybridization followed by selection during the segregating generations to produce a pure line variety.

Introductions consist of local varieties (land races) and varieties or populations from other parts of the world. These introductions are evaluated in replicated yield trials in the area of production and the best one may be selected as the first variety.

Selection within the best introductions (if heterogeneous) for some highly heritable trait such as height, maturity, seed weight or disease resistance can be used to produce an improved variety in some instances.

After the above methods have been exploited, the next procedure is to cross two desirable parent varieties that carry different (complementary) genes so that genetic recombination can produce an even better variety. It is the plant breeders job to select the rare superior recombinant.

Standard breeding methods have been developed to assist the plant breeder in his efforts to select the rare superior recombinant. These standard methods are the 1) Pedigree method, 2) Bulk Method, and 3) Modified Bulk Methods such as the Single Seed Descent Method.

Recently a highly effective and efficient modification of the bulk method, the F_2-Derived Family Method, has been developed (A modification, the F_3-derived Family Method, is nearly as efficient). The primary objective of a hybridization program is to create a wide array of genetic variation and then quickly and efficiently eliminate all but the best one or two families. The F_2-derived Family Method takes advantage of early generation yield testing of F_2-derived families to quickly and efficiently eliminate all but the better hybrid populations and all but the better F2-derived families within the best hybrid populations. This method was specifically devised for grain legumes with their high genotype by environment interaction (due to their indeterminate growth habit) and their low seed increase ratio which render the Pedigree, Bulk, and Single Seed Descent methods slow and inefficient. This method places primary emphasis on selection for yield, based on replicated progeny tests, and maximizes the opportunities to select for yield. This is important inasmuch as high yield is always one of the major objectives of every breeding program. This method can also reduce the time required to produce a variety.

F_2-DERIVED FAMILY METHOD

Generation	Procedure
1	Make crosses (produce F_1 seed)
2	Individual F_2 plants: Randomly select 200+ per cross
3	F_2-derived F_3: Single row plots, unreplicated, select among crosses but not within crosses.
4	F_2-derived F_4: Replicated 4-row yield trial at one site. Select families among and within crosses (50%)
5	F_2-derived F_5: Replicated 4-row yield trial at one site. Select families among and within crosses (50%)
6	F_2-derived F_6: Replicated 4-row yield trial at 2 to 3 sites. Select families among and within crosses (Best 5 families from each remaining cross).
7	F_2-derived F_7: Replicated 4-row yield trial at 2 to 4 sites. Select families among and within crosses (Best 2 families from each remaining cross). Also select 200 typical plants from each selected F_2-derived F_7 family.
8	F_2-derived F_8: Replicated 4-row yield trial at 2 to 4 sites. Plant 200 plant rows from each selected family and eliminate those that differ from the mean in morphological traits such as height, maturity, flower color, seed color, seed size, etc.
9	F_2-derived F_9: Replicated 4-row yield trial at 2 to 4 sites. Plant long plant rows of remaining plant rows of each selected family. Double check for uniformity in morphological traits including seed traits and bulk lines within a family to form breeder seed of the new cultivar.
10	New cultivar: Recheck seed yield of new cultivar during initial seed increase year.

Note that the only selection made within the final F_2-derived family was for morphological uniformity. Thus, this new variety will be heterogeneous for many other traits and this may give wide adaptation to the new variety.

In summary, a plant breeding program in a self pollinated crop starts with 1) Introductions, 2) Selection within the best introductions, and 3) Hybridization followed by selection using the Pedigree Method, Bulk Method or some modification of the bulk method such as the Single Seed Descent Method. A recently devised modification of the bulk method, the F_2-Derived Family Method, is presented in detail. It is quicker and more efficient than the other methods and may result in varieties with wide adaptation. It places maximum selection pressure on yield.

APPENDIX 11

Improving Efficiency of the Pure Seed Program

The primary function of a pure (pedigreed) seed program is to take breeder seed of a new variety and rapidly increase it so that large quantities of high quality seed (genetically pure, high germination and relatively free of weeds and other impurities) are available to farmers at a reasonable price. Plant breeding programs are continually producing new and better varieties and it is becoming more important than ever that these be increased and made available to farmers as soon as possible.

An efficient pure seed program is more important in grain legume crops than in any other type of crop, primarily due to the low seed increase ratio, that is, one grain legume plant produces on average only 10 to 30 seeds, whereas one wheat plant produces on average 50 to 150 seeds. Thus, it takes longer and requires more land to produce enough seed to plant 100 hectares of grain legumes than to plant 100 hectares of wheat.

Efficiency of a pure seed program can be increased by various means. Possible approaches are listed below many of which are already in place:

1. Organize a group of outstanding farmers from diverse areas of the country into a pure seed growers organization.

2. Establish standards for genetic purity, germination and freedom from weeds and other impurities.

3. Make small portable seed cleaning units, such as the Gjesdahl cleaner, available to the pure seed growers so they can meet quality standards.

4. Actively promote use of new varieties through appropriate Extension and Ministry of Agricultural initiatives. Some countries have used a subsidized seed exchange program to hasten adoption of new varieties.

5. New varieties should be promoted as part of a production package. In this way the 5% increase in yield of the new variety can be combined with the 10 to 20% increase in yield due to appropriate inputs and the difference will be readily apparent to the farmers. On-farm demonstrations work well in this regard.

6. The first increase of breeder seed should be thinly planted with highly effective weed control so as to maximize the seed increase ratio during this critical year.

7. The first increase of breeder seed should be subdivided into two or more lots and seeded in widely separated fields in the area of adaptation so as to reduce the probability that the breeder seed will be lost due to some natural catastrophe.

APPENDIX 12

Seed Placement Increases Efficiency of Fertilizer Phosphate

Soils rapidly fix fertilizer phosphate into a form unavailable to plants. Broadcast application of fertilizer phosphate maximizes contact between soil particles and fertilizer phosphate granules and results in rapid fixation. Proper placement of fertilizer phosphate will reduce soil fixation and increase the proportion of fertilizer phosphate available to the crop. Thus, fertilizer phosphate rates, properly placed, can be reduced to half the broadcast rates with comparable yield response.

The best placement of fertilizer phosphate is 2 cm below and 2 cm to one side of the seed with the seed in rows. However, a more practical method is to place the fertilizer phosphate with the seed in rows or hills. The main restriction to seed placement of fertilizer phosphate is that high rates, will reduce seedling emergence, especially if the fertilizer phosphate contains more than 5 to 10% nitrogen. Another restriction is that some crops, particularly pea (*Pisum sativum*), are very sensitive to seed-placed fertilizer phosphate and rates of phosphate must be kept below 20 kg P_2O_5/ha in rows and 10 kg P_2O_5/ha in hills.

Thus, seed placement of fertilizer phosphate can increase the efficiency of fertilizer phosphate and rates can be reduced to half the rate needed for broadcast application. This approach requires that the crops be seeded in rows or hills which also is beneficial from the standpoint of lower seeding rates and easier weed control.

APPENDIX 13

The Use and Misuse of Fungicidal Seed Treatments in Grain Legumes

Grain legume seeds require good aeration during the first 24 hours of water uptake or there will be a high incidence of seed rot. Seed rot is also a problem with seed lots that have damaged seed coats or in species that have a thin delicate seed coat such as kabuli (large-seeded) chickpea. Wrinkle-seeded peas have rough irregular seed coats which often are scratched or nicked during harvesting and seed cleaning operations and this type of pea often has a high incidence of seed rot when planted. However, with these exceptions, most high quality seed lots of grain legumes with intact seed coats have a very low incidence of seed rot, unless the soil is heavily contaminated by seed rot organisms such as *Pythium*.

Most cases of seed rot in grain legumes are caused by *Pythium* and the most effective fungicide against *Pythium* is metalaxyl (Ridomil). Metalaxyl seed treatment (6g active ingredient/100 kg seed) is required only when grain legumes are seeded into excessively wet, poorly drained or compacted soil(poor aeration), or when poor quality seed lots, seed lots with damaged seed coats, kabuli chickpeas or wrinkle-seeded peas are seeded. Fungicidal seed treatment has a limited effect on root rots caused by other fungi, and it has a depressing effect on the effectiveness of *Rhizobium* applied to the seed for nitrogen fixation. Thus, fungicidal seed treatment should be used on grain legumes only when there is clear evidence that it will be beneficial.

APPENDIX 14

Costs and Benefits of Agricultural Research

Governments often feel that agricultural research is just another expense item. However, agricultural research is actually an investment in the future that pays dividends in terms of increased production of higher quality food at a lower cost and thus it contributes to development of the country. In this way agricultural research provides an excellent return on investment.

There are also costs and benefits when a newly developed agricultural technology, such as a new variety, is disseminated throughout the agricultural community. This can be illustrated by means of a hypothetical example: Assume that the cash inputs for production of a specific crop are $100/ha and net returns (after expenses) are $50/ha. Then a higher yielding variety is developed that increases cash inputs to $110/ha, while increasing net returns to $80/ha.

The first farmers to use the new variety benefit markedly from this new variety (an extra $30/ha), relative to the remaining farmer.s These farmers usually are the bigger farmers, the better educated farmers, and the innovative farmers who can afford the extra cost of inputs with the promise of increased net returns. When half of the farmers have changed to the new variety, their average net return is $80/ha relative to the average net return of $65/ha for all farmers and $50/ha for those farmers who have not adopted the new variety. Before the last few farmers adopt the new variety, they are operating at a serious competitive disadvantage relative to the other farmers (net return of $50/ha vs. $80/ha for the other farmers), whereas they were directly competitive before the new variety was developed. Thus, it can be argued that agricultural research has hurt these farmers in relative terms. Unfortunately, this group of farmers includes the smaller farmers, the less educated farmers, the subsistence farmers and the poorer farmers who cannot afford the extra cost of the new inputs. These are the farmers who agricultural research is supposed to help. Actually, they do receive some benefits from agricultural research as consumers who have more and higher quality food available at a lower price.

It is inevitable that some of these farmers will be forced out of farming by economic circumstances, but this historically has been how countries develop economically - by reducing the percent of the population engaged in farming. This means increased employment opportunities must be made available somehow to these displaced farmers.

APPENDIX 15

Relative Merits of Agronomic and Plant Breeding Research

The objective of agronomic and plant breeding research is to improve the yield and quality of crops, while reducing per unit cost of production. Both agronomic and plant breeding research are required to meet this objective. Experience with long term research programs indicates that the average effects of agronomic research and plant breeding research are about equal in their contribution to increased yield and quality.

Initially, agronomic research has the potential to have a greater effect on yield and quality than plant breeding research. Thus, research results from experiments on seeding date, seeding rate and spacing, fertilization, inoculation, weed, disease and insect control, etc., can be demonstrated in farmer's field after only two to three years of positive results in research plots. On the other hand, results of plant breeding research require a long term approach and the new higher yielding variety may not be available for 10 years or so. Then, another three to four years of seed increase are required before enough seed is available for everyone. However, once a new variety has been developed, and seed is generally available, no additional costs are required. Chemical sprays must be used to control insects and diseases in many instances, but the least expensive and preferred approach is the use of resistant varieties.

Input costs will actually be reduced if the new variety has a markedly higher level of disease or insect resistance. Thus, the number of sprays can be reduced form 3 to 2 or from 2 to 1 or in some areas no spraying may be required. Development of disease resistant varieties will result in reduced use of dangerous insecticide and fungicide sprays and will be beneficial to the people and the environment. Thus, emphasis must be placed on development of insect and disease resistant varieties, once resistance has been found.

In some instances resistance is conditioned by a single gene with major effects. More commonly, resistance is conditioned by many genes with small additive effects which control the disease or insect by lengthening its infection (infestation) and reproduction cycle and reducing the level of reproduction. The end result may be termed tolerance in that the resistant plant is still infected (infested) but damage is reduced and yield and quality losses are minimized. This type of resistance (many genes with small additive effects) can best be attained for by selecting for yield since the tolerant plants will still exhibit symptoms. This further stresses the importance of breeding for yield as such.

In summary, both agronomic and plant breeding research are required to improve yield and quality of a crop. Benefits can be achieved much quicker from agronomic research, while it takes longer to achieve benefits from plant breeding research. However, plant breeding research will result in higher yield potential and a less expensive and less hazardous means of disease and insect control than by repeated applications of fungicides and insecticides.

Appendix 16

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