# Annual Report 1971

Centro Internacional de Agricultura Tropical, CIAT
Apartado Aéreo: 67-13. Cali, Colombia. S. A.
Cables: CINATROP

# Board of Trustees

(as of December 31, 1971)

# Contents

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(as of December 31, 1971)

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| Thomas A. Bloch, M.A.* | Assistant Scientist, Librarian |
| Don Bushman, Ph. D. | Ruminant Animal Nutritionist |
| Robert Cheaney, M. S. | Associate Agronomist |
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| Guillermo Galvez, Ph. D. | Associate Plant Pathologist |
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| Bela Grof, Ph. D. | Scientist, Pastures and Forages |
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| Neil Mac Lellan+ | Photographer |
| J.H. Maner, Ph. D. | Animal Scientist<br>Coordinator, Swine Production Systems |
| Fernando Monge, Ph. D. | Associate Communication Scientist |
| C.P. Moore, Ph. D. | Associate Animal Scientist<br>Coordinator, Animal Science Training |
| C.H. Mullenax, M.S., D.V.M.* | Associate Animal Pathologist<br>Coordinator, Livestock Production Training |
| Osvaldo Paladines, Ph. D. | Animal Scientist |
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| James M. Spain, Ph. D. | Soil Scientist; Leader, Agronomy |
| Roy L. Thompson, Ph. D. | Associate Agronomist |
| Gerald I. Trant, Ph. D.* | Agricultural Economist<br>Leader, Agricultural Economics |
| Amador Villacorta, Ph. D. | Assistant Entomologist |
| James L. Wilkus, M.P.V.M., D.V.M.* | Assistant Coordinator, Livestock Production Training |

### Special Appointments and Affiliates

| | |
|---|---|
| Kenneth Buhr, M.S. | Visiting Scientist, Food Legumes |
| Robert Etheredge | Architectural Consultant |
| Reinhardt Howeler, Ph. D. | Visiting Scientist, Soils |
| Julio Toro, M.S. | Study Leave |
| Gerrit Zemmelink, Eng. | Visiting Scientist, Animal Science |

### Texas A&M University Group

| | |
|---|---|
| Gary Adams, D.V.M., Ph. D. | Pathologist |
| Radmiro Todorovic, D.V.M., Ph. D. | Hemoparasitologist |

* Left during year.
+ On assignment from the Rockefeller Foundation.

# Foreword

This has been a transitional year for the Centro Internacional de Agricultura Tropical, a transition from project plans to research programs, from architectural drawings to completion of some of the principal structures, and from discussions about production systems concepts to field efforts to identify, describe, and understand the components of various systems.

These transitions have helped sharpen our objectives and to consolidate efforts toward achieving the basic mission of CIAT: To accelerate agricultural and economic development and to increase agricultural production and productivity of the tropics so as to improve the diets and welfare of the people of the world.

Several events helped management and staff to appraise present programs and to plan future activities. These included the Seminar on Strategies for CIAT in which all senior staff members participated in March, two meetings of the Executive Committee of the Board of Trustees, and two meetings of the Board.

Actions of the Board included the appointing of a three member Program Review Committee to meet in 1972 with the CIAT staff for a comprehensive analysis of the substantive aspects of the commodity thrusts, plus the decision to establish the position of Deputy Director General. In so doing, the Board recommended that the person selected for this post be primarily concerned with the international aspects of the CIAT programs and to provide direct leadership for overall agricultural production systems developments.

While the multi-commodity approach of CIAT is dictated by the diverse agricultural production systems and food customs of the countries and areas served, it became important to establish criteria to guide management and staff in the selection of individual programs as well as overall strategies. The highlights of the criteria which emerged this year through the Seminar on Strategies and subsequent discussions include the following components: Increase in real income, time for program pay-off to result, number of people served, income distribution effects, relationships with other agencies, input of CIAT resources required, nutritional importance, market potential, and the international nature of CIAT. This latter criterion suggests that CIAT select problems generally important in the lowland tropics and, of these, those least likely to be undertaken by other agencies.

## Program Highlights

The following paragraphs present a few highlights of the accomplishments and activities in CIAT's major programs during 1971.

**Beef.** In collaboration with ICA at Carimagua, a series of nine beef cattle production herds using grade Zebus native to the area were established to compare varying intensity beef cattle production systems. Presently available evidence indicates that beef cattle production levels and profitability could be substantially increased using sound pasture management, feeding, breeding and herd health practices, along with some improved pastures. This is a 5-6 year study which will be based on 324 heifers and the appropriate amount of pasture land.

One of the major limiting factors to increased livestock production in the interior and coastal plains of South America is the low nutritive value of native grassland. A wide range of genetic material of several important legume species is being observed at CIAT. Species of the leguminous genera **Stylosanthes, Centrosema, Desmodium, Glycine** and **Pueraria** are promising. The addition of a legume to the native grassland pastures to supply the necessary nitrogen for the soil-plant-animal complex is considered the most economical way to produce more beef per unit area at lower cost. Several high-yielding types of **Stylosanthes** have been identified, these including two provisional selections both native to Colombia. Seed of these lines is being increased. Perennial forms of **Stylosanthes** are of particular interest in the legume testing program. **Stylosanthes** is adapted to low fertility, acid soils and has the ability to extract phosphorus from soils low in this element.

Continuation of the animal health studies with blood parasites demonstrates that premunition (infected blood and drug therapy) is the method of choice at the present time to prevent clinical anaplasmosis and babesiosis in Colombia. This information is being used in field trials at Turipana. The use of premunition has, under controlled conditions, eliminated deaths in cattle moved into endemic zones, and the techniques developed for premunition are safe.

**Swine.** Seeking an on-the-farm source of protein to balance diets for hogs, swine nutritionists concentrated this year on seeking economical and practical means for processing cowpeas so as to reduce the digestive inhibiting factors they contain. Soaking was of little value; results with germinated cowpeas were inconsistent, but cooked cowpeas provided a protein that was well used by the pigs even when it was the only source of protein. Growth rates and feed conversion of pigs fed diets based on cooked cowpeas were similar to those of pigs fed standard control diets based on corn and soybean meal.

**Rice.** Adoption of the new high-yielding varieties of rice reached a significant level in 1971. Most of the area previously planted to high-yielding varieties had been in IR8, but the release in early 1971 of CICA 4 and IR22 leads to the expectation that these varieties will rapidly replace IR8 and will, in addition, be grown under many circumstances where IR8 has not.

CICA 4 has been accepted, multiplied and distributed in Ecuador as INIAP 6 and in the Dominican Republic as Advance 72. A sister line is being widely distributed in Peru under the name of Nylamp.

With the mounting interest in Latin America in the new rice varieties and the possible consequences of rapid increases in production associated with their planting, CIAT invited some 200 representatives of 23 countries to meet in Cali in October to consider the issues associated with rice policies for Latin America.

It was the purpose of this seminar to provide opportunities for decision makers to expand their horizons so that they can make better policy decisions. More specifically, it was to indicate ways and means by which rice productivity increases may be achieved on a broad scale and in such a way that these increases and productivity may benefit, in terms of improved real incomes and diets, the greatest number of persons in each country.

**Maize.** One of the goals is to produce commercial maize hybrids and varieties with wider adaptation for the range of micro-climates in the tropics. Photoperiod sensitivity limits north-south exchange of germ plasm, but field studies in 1971 revealed a simple inherited system for sensitivity —possibly as few as two genes— and this genetic pattern is being tested.

Search for a high quality maize with a flint endosperm continued. Laboratory and biological results are promising, and preliminary studies on nitrogen balance in children confirmed laboratory and rat data. The quality of the yellow flint selections is essentially equal to the original floury opaque-2 phenotype. In a white hybrid, H255, selection toward a crystalline endosperm was accompanied by reduced lysine and tryptophane levels as well as a lower biological value when fed to rats. Success in these selections, despite the problems with the white hybrid, indicate that a commercial version of opaque-2 with a more acceptable grain type may be available soon.

**Cassava.** Research in cassava was seriously hampered because of an outbreak of a bacterial infection, tentatively identified as **Pseudomonas** sp., in the collection and increase plots. This bacterial wilt is common in other areas of Colombia but had not recently been found in the Cauca Valley. To prevent the possible spread of the disease to commercial fields and other cassava collections, a vigorous attempt was made to eliminate the disease in the farm.

A low-cost cassava chipper was designed and built, and the economists surveyed cassava production methods in Colombia. Production costs appear to be equal on flat and sloping land with the techniques currently used.

The germ plasm collection of nearly 2,800 cultivars is being cataloged and various observations made.

Few varieties have produced a higher yield than Llanera, a variety collected by the Instituto Colombiano Agropecuario (ICA) from the Colombian llanos. Llanera consistently is one of the highest in crude protein content with about 6 percent. Although several other cultivars were found with intermediate to almost equal levels of nitrogen, Llanera was the only cultivar agronomically satisfactory under the conditions tested.

Another aspect of the rapidly growing cassava program is the plan to establish, as part of the Library, a Cassava Document Analysis Center. With the assistance of the International Development Research Centre of Canada, the unit will attempt to collect the available world cassava literature and publish a comprehensive annotated bibliography.

**Food Legumes.** Exploratory work in food legumes was expanded to include limited study of the available germ plasm with dry beans (**Phaseolus vulgaris**) and soybeans (**Glycine max**). Varieties of cowpeas (**Vigna sinensis**) and mung beans (**Phaseolus aureus**) have been screened for possible use in the tropics. A soybean study has demonstrated that it is possible to increase yield by genetically delaying the date of flowering, allowing the plant to grow larger before reproduction, and delaying the date of maturity. By setting these two character changes as goals, CIAT expects to get a taller plant, pods that form higher off the ground, and increased seed yield.

**Agricultural Production Systems.** Data from field surveys, experiences of production trainees on livestock ranches on the north coast and on small farms in the Cauca Valley, and observations of many farming operations in the tropics have helped identify the commonalities of the situations and the possible goals for cooperative efforts with national agencies with respect to agricultural production systems.

Regardless of the size or nature of the operation, it would seem that the agricultural production system goals for the people living on the land might well include the following: (1) Career opportunities in agriculture; (2) year-round adequate diets; (3) opportunity to produce, weekly or monthly, some cash income to supply the necessities they are not able to grow; (4) better housing and sanitation; and (5) improved educational and health facilities.

**Soils.** As the availability of reliable inoculants is a major problem in most of tropical America, soil microbiologists have tried to obtain cultures of **Rhizobium** for the forage and seed legumes important to this region. The some 100 different cultures obtained represent the most effective cultures in Australia, United States, Rhodesia and Brazil. These, preserved by freeze-drying, are available for distribution.

Work is now underway in Carimagua to identify acid soil tolerant lines of varieties, for use in crop improvement programs and for release for immediate farm use if such tolerance is combined with acceptable agronomic characteristics.

Work on the CIAT farm micro-nutrient deficiencies indicates that zinc, boron and iron are the most serious limiting factors in corn, sorghum and grain legumes. Zinc deficiency is most serious in rice, and the agronomists have obtained spectacular results with minimal applications of zinc in various forms.

**Agricultural Economics.** The impact of rapid expansions in production of selected agricultural commodities on such factors as price, incomes, income distribution, investment, employment and foreign trade is now being studied. Preliminary data indicate that considerable increases in the demand for meats may be expected. The demand for rice will increase at a somewhat slower pace while that for maize and cassava will increase moderately. Higher income families tend to consume less maize and cassava as incomes increase, while low income families tend to eat more of these foods at a modest rate. As their income increases, low income families tend to spend a greater proportion of their money for meat than do high income families.

**International Activities.** Throughout this report, CIAT scientists have detailed their activities to become familiar with and assist with the agricultural problems of various countries. Specifically, they have exchanged germ plasm, information, and other materials. Scientists are collaborating or assisting in several countries on beef, swine, rice, and corn projects, in addition to the cooperative work underway in several locations on plant disease, insects, and weed control. There is a constant flow of visitors from the countries to CIAT and from CIAT to the countries.

In addition, during the year 82 persons from 15 countries participated in CIAT training programs, including 32 as postgraduate interns in research and 25 as production specialists. Nearly 200 policy makers from 23 countries attended the Seminar on Rice Policies, while 16 scientists from all over the world presented a technical symposium to some 100 participants representing most of the rice-growing areas of Latin America. The IV Andean Zone Maize Conference attracted more than 50 persons from 12 countries.

### Administrative Developments

CIAT's financial base for operations expanded in 1971 with three governments, Canada, the Netherlands, and the United States, joining in the support of CIAT. Through the U.S. Agency for International Development, the Government of the United States became a full partner with the Rockefeller Foundation and the Ford Foundation in the basic core support with each of the three donors limiting their support to a maximum of $750,000 annually.

Through the Canadian International Development Agency and the International Development Research Centre, the Government of Canada established funds approximating $4,000,000 to help finance CIAT's research and training programs in swine and cassava. Most of these funds will be spent directly by CIAT, others in behalf of CIAT projects through Canadian institutions, and still others in connection with outreach functions in other countries. The Government of the Netherlands contributed $125,000 to the core program.

Special project funding during the year included support from the Interamerican Development Bank for the Seminar on Rice Policies and the production training programs, from the W. K. Kellogg Foundation to help finance general conference and symposia activities, and from the United States Agency for International Development, Washington, as well as AID country missions in Honduras and Panama for trainee support.

Changes in the CIAT senior staff during the year included five departures and ten arrivals. Those leaving were Dr. Charles Mullenax, to join the World Bank in Bogota, Dr. E. R. Roberts, to join the staff of the new College of Veterinary Medicine at Louisiana State University, Dr. James Wilkus, to join the International Veterinary Science Program, University of Minnesota, and Dr. Gerald I. Trant, to become Director General, Economics Branch, Ministry of Agriculture, Canada. Mr. Thomas Bloch completed his assignment as temporary librarian and became librarian for the Central American Institute of Business Administration in Nicaragua.

New arrivals were Dr. Donald Bushman, ruminant nutritionist; Mr. Kenneth Buhr, visiting scientist in food legumes; Dr. James Cock, plant physiologist; Dr. Jerry Doll, weed control specialist; Dr. Peter Graham, soil microbiologist; Dr. Bela Grof, pastures and forages specialist; Dr. C. Patrick Moore, training coordinator in animal science; Dr. Amador Villacorta, entomologist, and Mr. Gerrit Zemmelink, animal nutritionist on assignment to CIAT from the Wageningen University, the Netherlands. In addition, the Rockefeller Foundation assigned Mr. Neil Mac Lellan, experienced agricultural photographer, to CIAT for an indefinite period to assist in the development of our photographic services.

Despite the unseasonal weather, labor and material shortages, and soil problems, contruction continued on the physical plant. At year's end, Station Operations was occupied, with more than 50 percent of the space being used as temporary offices and laboratories for commodity programs. Other buildings, expected to be ready for occupancy in the first quarter of 1972, included the Small Animal Colony, Field units for the beef and swine programs, and the green and screen houses. The agricultural engineer, continuing the development of the experimental farm, used this as an opportunity to train a number of young engineers in the various phases of development and operation.

Upon the departure of Mr. Bloch, Dr. Fernando Monge, associate communication specialist, was named as librarian. In addition to this principal responsibility, he will continue his active participation as a social scientist in various research and training activities of CIAT.

Mr. Herant Akmajian, a consultant generously provided by the Ford Foundation, assisted significantly in the revision and establishing of new accounting systems and records. Similarly, the late Dr. Henry Tucker, professor of systems engineering, University of Arizona, provided the staff and trainees with considerable guidance and information on statistical and systems engineering matters during a two-week visit to CIAT in March. His sudden death while working at his desk at the university later in the year was a shock to his many friends, students, and professional colleagues.

# Beef

## Production Systems

A viable beef cattle industry can significantly contribute to the overall economic development of countries and regions in the tropical belt. Beef cattle provide the mechanism for the rational use of extensive pasture land not suitable for crop production, as well as the immediate utilization of potentially arable lands for grazing until the necessary infrastructure for crop farming develops. Beef cattle can transform these pastures and forages, as well as other cellulosic crop residues and by-products, into high quality animal protein for human consumption. These feedstuffs have no nutritive value for man, poultry or non-ruminants, but produce real income when fed to ruminants.

Also, in many countries an expanded beef industry would not only supply additional animal protein for human consumption, but would provide beef for export above effective local demand. These export earnings are often critically needed to support country development. Since both internal and export demand for beef are strong, it would appear advantageous for those lesser developed countries with high beef production potential to exploit this opportunity to increase beef exports.

Research and training programs are underway at CIAT in Palmira, the ICA Carimagua station situated in the llanos and the ICA Turipana station located near Monteria on the north coast. CIAT is assisting the INIAP Beef Cattle program in Ecuador. It is anticipated that CIAT staff will cooperate at other locations in Latin America when current programs become sufficiently developed.

Projects with outside funding include the Texas A&M University hemoparasite project, and a project involving visiting scientists from Wageningen. The Texas A&M hemoparasite project is completely financed by USAID. A portion of the funds is used to support graduate training and research in hemoparasite diseases at Texas A&M, and the remainder to support graduate student thesis and other research in CIAT. Wageningen provides salary and other perquisites for its visiting scientists.

The following describes the participation of various professional groups as related to specific research and training objectives in developing beef cattle production systems for the lowland tropics.

Specific research objectives are (1) to provide adequate feed supply, (2) to control disease and parasitism, and (3) to develop economical systems of production and marketing. Specific training objectives include training of professionals as production and research specialists.

### Feed Supply

Soils, soil bacteriology, weed control, pastures and forages, and animal nutrition specialists collaborate in developing beef cattle feeding regimes. Year-round feed supply and adequate life-cycle nutrition are probably the most critical factors affecting reproductive performance, growth rate, and susceptibility to disease and parasitism. Primary attention is given to grazing systems, with supplementation only as needed to correct nutrient deficiencies. In addition, the use of other feedstuffs in more intensive beef cattle production systems is considered.

### Agronomy/Soils

Development of a beef cattle industry based on grazing systems depends directly upon the inherent productivity of soils on which these pastures are grown, and the influence of soils type on forage yield and nutritive value.

**Soils fertility.** In Carimagua, scientists have screened certain forage legumes and grasses for fertilizer requirements, and have cooperated in the establishment of the molasses grass (**Melinis minutiflora**) grazing experiment using three fertilization regimes. Studies will be continued to determine time and fertilizer (especially phosphorus) requirements of best adapted pasture grasses and legumes, as well as methods of fertilizer application.

**Soils Management.** Molasses grass and **Calopogonium muconoides** have been successfully established in Carimagua with no mechanical seed bed preparation. These studies will continue to test selected tillage methods and chemical weed control to reduce costs, machinery requirements, management of residues and control of weeds.

**Soil microbiology.** A freeze-dried collection of **Rhizobium** cultures for most species is now ready and is being supplied to collaborators on request. Field and greenhouse testing of culture is in progress.

### Pastures and Forages — Agrostology

One of the major limiting factors to increased livestock production in the interior and coastal plains of South America is the low nutritive value of native grasslands consisting of mono specific grass swards and inferior fire sub-climax vegetation. The addition of a legume to supply the necessary nitrogen (protein) for the soil-plant-animal complex is considered the most economical means of producing more beef per unit area at lower cost.

Scientists in the agrostology program have identified the following priorities:

1) Collection, introduction and screening of tropical forage species, with particular reference to tropical forage legumes.

**Seed increase plot of guinea grass accession from East Africa.**

Forage legume introduction garden at CIAT farm.

Vigorous $F_3$ generation of a Centrosema brasilianum X C. virginianum hybrid.

CIAT scientist and Costa Rican trainee inspect promising Stylosanthes cultivar.

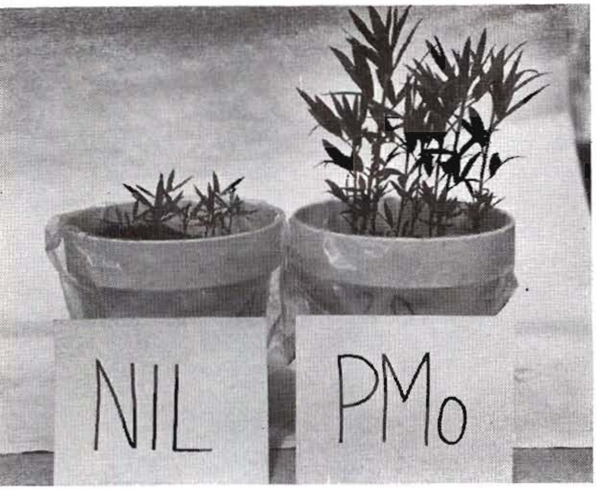
2) Development of superior cultivars of forages and grass-legume mixtures adapted to pasture utilization.

3) Study of practical and economically feasible pasture establishment and range re-seeding techniques, with emphasis on legume introduction into existing native pastures.

4) Study of possible solutions to overcome limiting soil fertility.

5) Seed production and regional evaluation of selected forage species.

6) Evaluation of forages by livestock.




Stylosanthes guyanensis responded strongly to fertilizer application on a Carimagua latosol.


**Pasture Plant Introduction and Evaluation.** A wide range of genetic material of several important legume species is being observed at CIAT. Species of the leguminous genera **Stylosanthes, Centrosema, Desmodium, Glycine** and **Pueraria** show promise. New accessions and indigenous materials are being added to the existing germ plasm collection from other tropical regions.

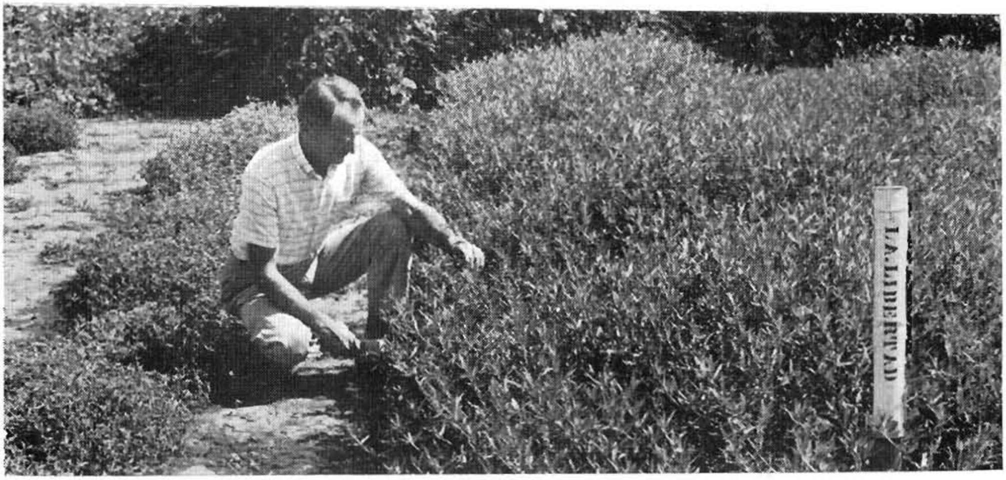
**Stylosanthes.** The perennial species (**S. guyanensis**) is a naturally occurring component of pastures in Colombia. It is found from sea level to 1,700 m in many forms and biotypes. The wide range of variability observed in this polymorphic species warrants detailed agronomic evaluation. The selection of productive types, adapted to pasture conditions, is in progress. Several high-yielding types have been identified. These include two provisional selections, both native to Colombia, one accession from Costa Rica and one from Brazil. Seed of these selected lines is being increased.

Experiments at pilot plots in Carimagua indicate that several tropical forage legumes, e.g., the perennial species of Stylo, **Pueraria phaseoloides,** and **Calopogonium muconoides,** are adapted to the llanos environment.

**Centrosema. Centrosema pubescens** is widely recognized as a tropical forage legume, but other species of this genus have not received attention as cultivated forages. $F_3$ and $F_4$ populations derived from the interspecific cross **C. brasilianum** x **C. virginianum** are being assessed in a space-planted nursery. Selection for important agronomic characters, including yield, stoloniferous development, and late seeding habit, were carried out. Twelve selected lines are being propagated clonally for further testing and seed production.

**Desmodium.** A range of ecotypes of both **D. intortum** and **D. uncinatum** are under observation and seed increase. Some of these were collected locally, others in Ecuador. The browse legumes **D. distortum** and **D. heterophyllum** are promising.

**Glycine** and **Teramnus.** Introductions from Southern Rhodesia, Australia and




**Promising variety of** Stylosanthes guyanensis **from the Colombian Llanos.**

the local variety show good agronomic characters and adaptations to Cauca Valley conditions.

**Plant nutrition.** Interest is concentrated on the latosols, red-yellow podsolics and other marginal soil types. These soils are generally low in plant nutrients, notably in phosphorus and nitrogen; they have a low base exchange capacity and are acid in reaction.

**S. guyanensis,** grown in pot culture on Carimagua latosol, responded strongly to phosphorus addition, but not to potassium application. Maximum dry matter yield was obtained at 26.2 kg/ha phosphorus level. A higher application

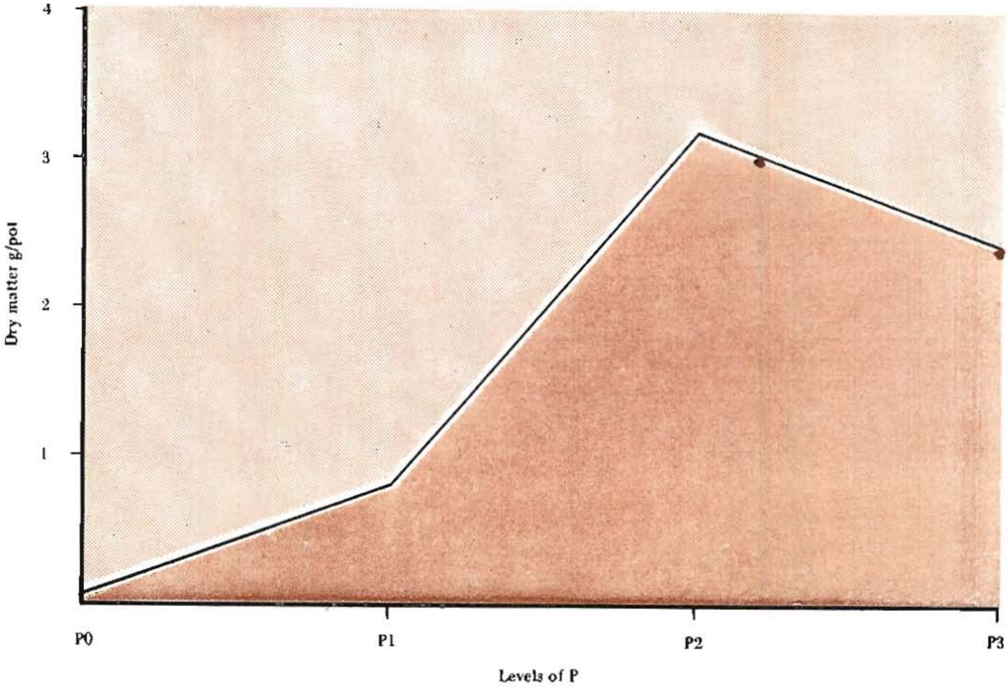



FIGURE 1. Yield response of **S. Guyanensis** to four levels of P, e. g.: P0 = control, P1 = 13.1, P2 = 26 2 and P3 = 52.4 kg/ha.

rate—52.4 kg/ha—of phosphorus gave no further increase in dry matter yield (see Fig. 1, page 15).

The effect of four micro-nutrients (Mo, Zn, Cu, B) in combination with phosphorus and potassium on the establishment of Stylo was studied in another pot experiment. Again, phosphorus gave the largest dry matter increase and showed a phosphorus x molybdenum interaction. Without phosphorus, all other elements were ineffective.

**Seed production.** To reach even a fraction of the pasture production and grazing potential of the tropics of Latin America, enormous quantities of seed of selected grass and legume species will be needed. At present there is no organized forage seed production in Colombia.

Bulking up of seed of stylo selections, centro, kudzu, glycine, greenleaf desmodium, **Brachiaria decumbens, B. ruziziensis** and **Paspalum plicatulum** was initiated.

### Pasture and Forages — Utilization

The feed supply for the beef cattle industry of the lowland tropics is based upon year-round pasture forage. There are extensive pasture lands which could support an expanded beef cattle industry. Unfortunately, these pasture lands are either poorly managed and sometimes overgrazed or are grossly under-utilized.

The pastures and forages utilization program focuses on methods (1) to increase productivity of existing grasslands, and (2) to further increase productivity using tropical legumes and improved grass species.

### CIAT Center

Two grazing trials have been initiated to determine live weight gain and costs of production in intensive systems of growing-finishing beef cattle using Pangola (**Digitaria decumbens**) and Para (**Brachiaria mutica**) pastures.

**Pangola grazing experiment.** Four nitrogen fertilization rates (200, 400, 600, 800 kg N/ha/yr) and rotational grazing with three stocking rates are used. Gravity irrigation is provided as needed. This experiment was delayed because of the redesign of the irrigation system and the slow growth rate of the Pangola grass resulting from soil fertility problems and a high water table.

Possible reasons for this slow growth rate are (1) micro-element deficiencies including zinc, iron and boron as suggested by that observed with rice and soybeans, (2) salinity, especially where land leveling cuts were made, and (3) high water table. Exploratory trials are being initiated to determine possible soil micro-element deficiencies affecting growth of Pangola.

**Para grazing experiment.** This trial was begun in November, 1971. Three nitrogen fertilization rates (200, 400, 600 kg/ha/yr) are being compared using a rotational grazing system. This experiment will continue for two-three years. Whereas Pangola appears to be highly sensitive to soil mineral deficiencies, soil salinity, and high water table, Para is much better adapted to these conditions.

**Diethylstilbesterol and Vitamin A.** The effects of implantation of diethylstilbesterol and Vitamin A on growth rate were determined in grade Zebu bulls and steers maintained on pasture during the growing-finishing period. Duration of this trial was 672 days. A total of 284 animals was used. Twenty-one bulls and eight steers failed to reach the 450 kg slaughter weight.

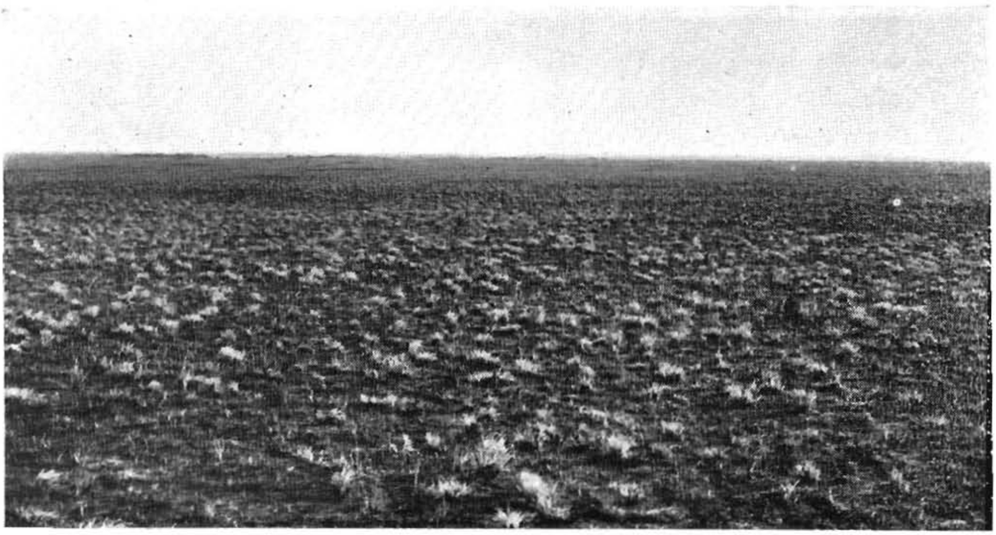
Table 1 presents average weight gains of bulls and steers calculated by three-four month periods. The heavier animals and the best gainers were sold first.

These data indicate that diethylstilbesterol implantation increased average weight gains in steers by 13 percent during the entire experiment, but did not effect the bulls. The greatest response to diethylstilbesterol was obtained in the initial stages with the

TABLE 1. **Daily gain of weight of steers and bulls implanted with Vitamin A and diethylstilbestrol.***

| **Steers**<br>**Treatment** | Dec. 1969<br>Feb. 1970 | Feb. 1970<br>May 1970 | May. 1970<br>Sept. 1970 | Sept. 1970<br>Nov. 1970 | Nov. 1970<br>Feb. 1971 | Feb. 1971<br>May 1971 | May 1971<br>Oct. 1971 | Mean<br>Dec. 1969<br>Oct. 1971 |
|---|---|---|---|---|---|---|---|---|
| Control | 519 | 427 | 480 | 262 | 241 | 459 | 371 | 388 |
| Vitamin | 493 | 435 | 514 | 224 | 205 | 445 | 488 | 388 |
| DES | 668 | 521 | 567 | 151 | 188 | 558 | 234 | 439 |
| Vitamin-DES | 596 | 526 | 558 | 176 | 262 | 366 | 342 | 439 |
| Mean | 569 | 477 | 528 | 202 | 220 | 464 | 365 | —— |
| **Bulls** | | | | | | | | |
| **Treatment** | | | | | | | | |
| Control | 747 | 408 | 595 | 281 | 334 | 536 | 498 | 446 |
| Vitamin | 532 | 486 | 579 | 244 | 292 | 507 | 380 | 450 |
| DES | 618 | 523 | 591 | 178 | 280 | 499 | 340 | 456 |
| Vitamin-DES | 607 | 561 | 571 | 213 | 268 | 455 | 471 | 447 |
| Mean | 632 | 494 | 584 | 218 | 288 | 451 | 501 | —— |

* Reimplanted every 120 days with 30 mg diethylstilbestrol and 400 IU Vitamin A.



Regrowth of native savannah after burning.

Clearing a path for fencing in the eastern plains of Colombia.

faster gaining steers, with a generally negative response with slower gaining steers during the later phases of the finishing period.

Injection of Vitamin A had no effect, indicating that pasture forage supplied adequate carotene.

**Turipana**

An intensive grazing trial is being initiated to determine costs of production and live weight gains of steers grazing Para grass with and without the tropical legumes **Centrosema plumieri, Desmodium intortum, Clitoria ternatea, Pueraria phaseoloides.** Three stocking rates will be compared using rotational grazing.

Basic concerns are: probable productivity and economic advantages of interseeding legumes with Para, and identification of optimum pasture management regimes to maximize productivity and profit.

**Carimagua**

Carimagua, in the heart of the Colombian llanos, typifies extensive latosol grassland areas in Venezuela, Brazil, Bolivia and Colombia. Many of the native species are of low nutritive value. Primary attention is being given to determining (1) most efficient methods of native range management, (2) possibilities of establishing improved grass pastures, and (3) efficacy of interseeding tropical legumes in both native and improved pastures.

**Molasses grass (Melinis minutiflora) grazing trial.** A trial was initiated in October, 1971 to determine amount and cost of live-weight gain of cattle native to the Colombian llanos grazing molasses grass pastures. Fertilizer treatments at time of establishment included no fertilizer, 75 kg $P_2O_5$/ha, and 75 kg $P_2O_5$ plus 40 kg K/ha. Three stocking rates are used, 0.5, 1.0, 1.5 animals/ha.

Average daily weight gains after 56 days grazing are presented in Table 2.

TABLE 2. **Weight gains of animals grazing molasses grass.***

| | Stocking Rate, Animals/Ha. | | |
|---|---|---|---|
| | 0.44 | 0.88 ADG gms | 1.30 |
| No fertilizer | — 2 | — 89 | — 15 |
| Phosphate | —242 | —346 | —193 |
| Phosphate + potash | —385 | —448 | —454 |

* Initial 56 day period.

During this period and until the end of the dry season, reduced stocking rates are used to protect the pasture, as little information is available regarding effect of stocking rate.

All treatments resulted in weight losses during this period, the beginning of the dry season. At this time molasses grass flowers and goes to seed, vegetative growth stops, and pasture palatability and nutritive value decline. Relatively minor losses were observed in the unfertilized pastures as compared to the fertilized plots. This perhaps was because delayed flowering and seeding in unfertilized plots produced a more nutritious pasture forage than in the fertilized pastures.

**Native pasture.** This trial was initiated in September, 1971 to determine amount and cost of live-weight gain of native cattle grazing pastures native to the Colombian llanos. Predominant grass species include **Trachypogon vestitus, Andropogon bicornis** and **Axonopus purpusii.** Continuous and rotational grazing systems are being compared using three stocking rates, 0.20, 0.35 and 0.50 animals/ha. It seemed advisable to initiate the trial with lower stocking rates because of the approaching dry season and lack of information using stocking rates heavier than 0.20 animals/ha.

Results to date are shown in Table 3. Average daily weight gains were least at the highest stocking rate as compared to the lower stocking rates using both rotational and continuous grazing.

TABLE 3. **Weight gains of animals grazing native pasture.***

| System | Weight gains | Stocking rate Animals/Ha. 0.15 | 0.23 | 0.37 |
|---|---|---|---|---|
| Continuous | ADG, gms | 311 | 319 | 274 |
| | Per Ha., Kg | 4 | 7 | 9 |
| Rotational | ADG, gms | 256 | 270 | 83 |
| | Per Ha., Kg | 3 | 6 | 3 |

* Initial 85 day period.

Weight gains per hectare increased as stocking rate increased using continuous grazing, but was erratic with rotational grazing.

Note both the apparent advantage of native grass during the dry season as compared to molasses grass and the average daily gains of approximately 300 grams for animals grazing the native pasture during the onset of the dry season. Compensatory growth gains can be discarded, as all animals had been grazing similar native grass pastures for more than four months prior to the start of this trial.

**Typical Criollo cattle at Carimagua.**

**Beef Cattle Nutrition**

The beef cattle nutrition program is placing emphasis on (1) the nutritional factors limiting reproduction and growth rate, and how these can be resolved, and (2) beef cattle feeding regimes in more intensified farming systems.

Primary attention will be given to minerals, energy and protein, which appear to be the most critical nutritional factors affecting reproductive and growth performance.

In determining the possible role of beef cattle in more intensified systems during the next two years, the primary work emphasis will be on the feed value and productivity of certain cultivated forages, crops, crops residues and by-products. The data obtained on each of these potential feed stuffs can be directly applied to more intensive crop livestock enterprises including: (1) farms of intermediate size which produce crops such as corn, cassava, sugar cane, rice, cotton, etc., (2) dairy-beef, and (3) small, highly intensified crop-livestock units.

**Control of Disease and Parasitism**

**Animal Health**

The primary objective of the animal health program is to improve reproductive and growth performance and reduce mortality through control of disease and parasitism, with particular attention to causes of reproductive failure resulting in lowered calving percentages, and to generally high mortality of calves from birth to weaning.

The program includes investigations of toxic plant problems, selected disease agents, and the Texas A&M hemoparasite project.

**Toxic Plants**

The study of enzootic hematuria, probably caused by bracken fern (**Pterdium equilinum**) which causes chronic blood loss in the urinary bladder, continued. Calves on pastures which in the past had produced a high incidence of the disease were studied for eight months. While at least one of them developed the disease, no changes in the serum values measured were observed which might give an indication of the etiologic agent. The study of this disease was discontinued. There is no doubt that it causes severe losses in intermediate elevation areas, but it is not a problem in the tropical lowlands.

Toxic plant studies continued in Turipana. The weed Anamu (**Petiveria alliacea**) was identified as one responsible for a syndrome locally called "vacas caidas", which is characterized by lack of coordination and muscular dystrophy, particularly in calves.

A preliminary investigation which tried to associate the weed "Rosa vieja" (**Lantana camara**) with photosensitivity (piel caida) was unsuccessful, probably because of lack of sunlight during the feeding trials.

**Selected Disease Agents**

The search for the route of the infection with Vesicular Stomatitis Virus (VSV) continued on a farm near Popayan. Despite a 40-year knowledge of the two virus types in this group, the source of the virus in nature and the route of infection are not known. In related study with VS virus, no evidence was found that bovine leucocytes play a role in the pathogenesis of VSV infection in the bovine.

A preliminary investigation of bovine papillomatosis on a large farm in Antioquia, where this viral infection leads to a cancerous condition which causes severe losses of livestock, concluded that the problem seems to be only of local importance.

During 1971 a serum bank was established and at year-end some 3,000 specimens were stored.

**Texas A&M Bovine Hemoparasitic Disease Project**

Bovine anaplasmosis, babesiosis and trypanosomiasis are arthropod-transmitted blood diseases which are associated with either anemia and death or large production losses in surviving cattle, particularly in tropical areas.

Hemoparasitic disease research and training continued at the ICA-LIMV research laboratory in Bogota until September, 1971, when the unit was moved to CIAT.

The infective agents of bovine anaplasmosis (**Anaplasma marginale**), babesiosis (**Babesia argentina** and **Babesia bigemina**) and tryponosomiasis (**Trypanosoma vivax, Trypanosoma evansil**) were isolated and purified from spontaneous bovine field cases. The purified isolates were stored by a low temperature method and used in laboratory and field experiments. Ultrastructural studies were performed on **B. bigemina** and **T. vivax** for comparative purposes.

Microscopic and serologic diagnostic methods were developed and applied on a limited scale to the study of the incidence and prevalence of hemoparasitic diseases of cattle in Colombia. The survey made of these infections in Colombia has clearly identified the problem areas, as well as the clean areas. The correlation of **Anaplasma** and **Babesia** incidence with various climatic zones reveals a pattern which would provide valid information for all parts of Latin America.

The preparation of slides of blood parasites.

Pathogenesis studies of single and multiple hemoparasitic infections in cattle have significantly elaborated on the virulence, disease mechanisms and host reaction to the causative agents.

Research demostrates that premunition (infected blood and drug therapy) is the method of choice at the present time to prevent clinical anaplasmosis and babesiosis in Colombia. This information is being used in field trials at Turipana. The use of premunition has, under controlled conditions, eliminated deaths in cattle moved into endemic zones, and the techniques developed for premunition are safe.

Experiments were conducted to evaluate the prophylaxis, therapy, effect, dosage, route of inoculation, toxicity and response of the animals injected with new drugs for anaplasmosis and babesiosis. The synergistic effects of combined drug therapy are currently in use in Colombia as a treatment to moderate **Anaplasma** and **Babesia** premunizing infections.

Experiments were executed to identify arthropod vectors of anaplasmosis and babesiosis. **Boophilus microplus,** a tick, was identified as the principal vector. The ticks have been purified and maintained under laboratory conditions. The vector of bovine trypanosomiasis was not identified.

Attempts were made to develop effective diluted infected blood, irradiation attenuated, killed, and adjuvant vaccines to control hemoparasitic diseases of cattle. Under experimental conditions, some of these vaccines have exhibited promising results for further study and application.

Some of the projects in progress include the following: **In vitro** cultivation of **Babesia bigemina,** development of a **Babesia** vaccine utilizing infected tick tissues, development of a fluorescent antibody diagnostic test for bovine trypanosomiasis, analysis and comparison of **Babesia** antigens, development of a **Babesia** rapid card agglutinations test, study of strain immunity, study of the effect of molasses grass on tick populations, and others.

## AGRICULTURAL ECONOMICS

### Economics of Production and Marketing

The agricultural economists worked closely with animal scientists. Besides collaboration on experimental designs, a major research project was initiated and two projects were planned in 1972.

**Colombian Beef Cattle Sector.** A research project aimed at describing the Colombian beef cattle sector is in progress. The primary objective is to produce information on the basis of which the CIAT beef cattle program may establish guidelines for future activities. In addition to serving CIAT, the information will be useful to other national and international agencies in establishing guidelines for credit, technical assistance and general public policy issues.

Basic information is obtained from surveys among beef cattle producers. The information sought includes such matters as management practices with respect to cattle and pastures, credit, technical assistance and marketing.

A survey has been carried out among 487 ranchers in the north coast region of Colombia. The data are presently being analyzed. Tentative results indicate that for the north coast region average calving rates are about 61 for all farms, with slightly lower rates (55) for farms larger than 500 ha, and 62 for farms less than 500 ha. Variation among zones in the region is from 36 to 80.

General rates of mortality in the region range from 2.2 to 10; the average for the region is estimated to be 4.4 percent. Higher mortality rates are associated with smaller farms.

Stocking rates vary from 1.3 head per hectare to nearly 2 per hectare with the average being about 1.5 head per hectare.

**Cost of production.** An in-depth analysis of the cost of producing beef cattle in the north coast has been planned for 1972.

## AGRICULTURAL ENGINEERING

Agricultural Engineering and Station Operations have provided leadership, training and supervision in the implementation of long span fencing, irrigation, drainage, water supply and pasture establishment for the experiment station areas at CIAT to be used in beef research and beef cattle production.

Long span fencing with reinforced concrete corner posts and horizontal braces reduced total costs and provided more permanent fencing.

## BEEF CATTLE PRODUCTION SYSTEMS

Beef cattle production levels are generally low in all the tropics of Latin America, particularly in latosolic grassland areas in the Colombian llanos and the Campo Cerrado of Brazil. Preliminary evidence indicates that productivity and profitability could be substantially increased using sound pasture management, feeding, breeding and herd health practices, and using some improved pasture.

All CIAT beef cattle research projects are directed towards contributing technology for the development of complete beef cattle production systems in the tropics. This technology, combined with available knowledge, will be used in determining productivity and profitability of various life-cycle beef cattle production systems.

In collaboration with ICA at Carimagua, a series of nine beef cattle production herds using grade Zebus native to the area were established to compare varying intensity beef cattle production systems. Comparisons include (1) traditional versus improved cattle and pasture management systems, (2) native grass versus native plus some improved grass (**Melinis minutiflora**) versus all improved grass (**Melinis minutiflora**), (3) continual back crossing with Zebu bulls versus rotational cross breeding using Zebu and San Martinero, a local breed, (4) mineral supplementation versus no mineral supplementation on native grass, and (5) effect of continuous versus seasonal breeding on calving percentage. In addition, the effects of protein and energy supplementation on reproductive performance of cows grazing native, native-**Melinis minutiflora** and **Melinis minutiflora** pastures will be determined by providing supplemental feed for a portion of the cows in selected herds on these three pasture systems.

This study will use 324 heifers and approximately 2,500 hectares of pasture. Duration of the experiment will be five to six years. A similar replication of this experiment will be established in late 1972 and early 1973.

## TRAINING AND COMMUNICATION

Specific training objectives include training of livestock specialists qualified to analyze, program, implement and supervise livestock enterprises; in-service type training in a specific area to better equip various livestock specialists to direct research and training programs in their specialty areas; and direction of thesis research of selected graduate students.

**Other trainees.** Since the inception of the beef cattle program in mid-1969, nine postgraduate interns and five graduate student thesis research projects have been completed in pastures and forages, animal husbandry and animal health. These trainees have come from Colombia, Ecuador, Brazil, Costa Rica and the Netherlands.

**Texas A&M.** Two Colombian and eight North American veterinarians have received advanced training in tropical veterinary medicine with emphasis on bovine hemoparasitic diseases. Of the ten veterinarians, three have received the Master of Science degree and one the Doctor of Philosophy degree.

### Outreach

Members of the beef cattle team have visited Mexico, Venezuela, Ecuador, Peru, Bolivia and Brazil to select trainees, provide technical counsel and to become familiar with the livestock industries.

A unified program of plant introduction and evaluation has been arranged in collaboration with national pasture and forages programs of Bolivia, Colombia, Ecuador, Peru and Venezuela. Because of international interests, CIAT has an opportunity to coordinate the scientific assessment of potentially valuable forage and fodder species, maintain a germ plasm bank, and take care of the dissemination of promising forage species.

The CIAT beef cattle team is a member of a Technical Advisory Committee for the INIAP Beef Cattle Program.

Papers were presented by CIAT staff members at the third meeting of the Latin American Association of Animal Production (ALPA) in Bogota, and at the World Congress of Veterinary Medicine and Animal Husbandry held in Mexico City. Dr. Osvaldo Paladines, CIAT Animal Scientist, was elected president of ALPA.

Members of the CIAT hemoparasite project established a scientific working relationship with members of the Instituto Veterinario de Investigaciones Tropicales y de Altura (IVITA) located at Lima, Peru and with members of the East African Veterinary Research Organization located at Muguga, Kenya. Emphasis was placed on a strong international working relationship in the field of bovine hemoparasitic diseases.

A CIAT staff member presented a series of lectures on the nutrition of grazing animals in an intensive beef cattle nutrition course held in Turrialba, Costa Rica. This short course was desiged for investigators in universities and national research institutes.

# Cassava

## Production Systems

The 1971 Cassava Program continued to establish and evaluate **Manihot esculenta** variability. This will be used in development or selection of varieties with improved resistance to disease and insects and having desirable agronomic characteristics. The variability of types is being studied to ascertain the possibility of using cultural practices which will increase the amount of cassava produced per unit of land per unit of time. Small plant types which mature early offer the potential for equal total productivity when compared with late, more vigorous types. But these will probably require modifications in plant populations, fertilization, and harvest time.

Rainfall during 1971 was considerably above normal and resulted in high water tables in some experimental areas. Since cassava cannot tolerate saturated soil conditions, the heavy rainfall caused root spoilage and the loss of yield and root developmental data from many cultivars.

An infection caused by a bacteria tentatively identified as **Pseudomonas** sp. occurred in the collection and increase plots. This bacterial wilt is common in other areas of Colombia but had not recently been found in the Cauca Valley. To prevent the possible spread of the disease to commercial production fields and other cassava collections in the area, a vigorous attempt was made to eliminate the disease.

Experimental work indicated the bacteria are found mainly in the nonlignified stem tissue, and cutting back plants below the infection along with other sanitation practices reduced the amount of infection. All experimental trials, increase plots and bulk fields and all but four plants from each collection were destroyed. These remaining plants were cut 50 cm from the ground and the top material destroyed. All refuse material was cleaned from the areas and the regrowth observed at least twice a week for reinfection. Any reinfected plants were then either destroyed or cut back to ground level.

Reinfection was found in about 10-15 percent of the plants, but with the coming of the dry season the biweekly inspection showed a considerable reduction in number of reinfected plants. The eradication of the bacteria necessitated a reduction in other activities within the program. With the decreased occurrence of infected plants, in-depth research efforts are being renewed.

Areas where work has been conducted with cassava in 1971 include agricultural engineering, agricultural economics, agronomy and germ plasm evaluation, entomology, plant pathology, and weed control.

**Agricultural Engineering**

In cooperation with agricultural engineering, station operations and agronomy, a low cost cassava chipper similar to a type used in Thailand was designed and built (Fig. 1). This prototype chipper uses a barrel end as a rotating grater (Fig. 2) which is attached to a power shaft driven by a tractor power take-off. The total cost of this chipper was less than US$100. Future models could possibly be built for less than $50 without the power unit. A gasoline engine or electric motor can readily serve as a power source. A hand powered unit will be tested where cassava needs are limited or where lack of capital prevents a greater investment.

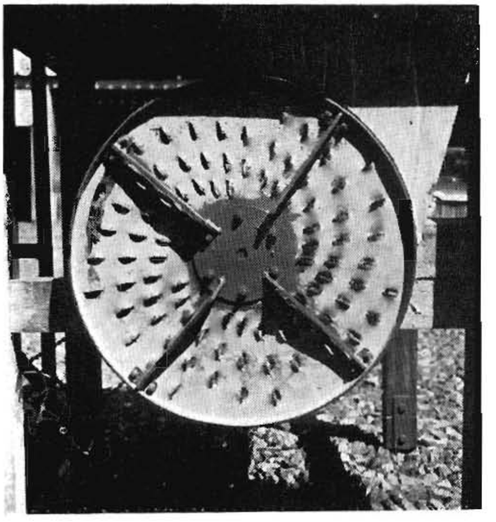


FIG. 2. Close-up of the cassava chipper blade made from the end of a 55-gallon oil drum.

FIG. 1. Testing the "barrel head" cassava chipper, which uses a tractor for power.

Limited tests of the chipper indicate a capacity between 1,500 and 2,000 kg of fresh roots per hour. The machine produced chips or flakes about 1 1/4 cm wide, less than 1/2 cm thick with a variable length. The thickness of the chip will depend on the size opening of the hole in the chipper blade.

Because the cutting edges of the chipper are not sharp, there appears to be a tearing action on the chip, which may lead to a faster drying rate. Chips spread on a concrete floor in full sunlight are dried to a moisture content of 15 percent in one day.

Agricultural engineering gave technical advice and operating support to the Cassava Program on the determination of specific gravity, heat treatment of seed pieces, and description of the root distribution of the plant. In addition, equipment was provided for bed making, irrigation, drainage, transport of cassava, and for eradication of diseased cassava within the quarantine zone.

**Agricultural Economics**

The following economic studies relating to cassava were conducted:

1. A compilation of FAO data for the last 10 years which indicates the production, yield and production per capita of cassava on a world, regional and country basis. The data suggest that although total cassava production continues to increase, it tends to do so less rapidly than population.

2. A survey of cassava production methods in Colombia was started in 1971; results from 110 questionnaires indicate the following tentative results. Production per hectare per month where cassava is cultivated on relatively flat land is positively correlated with: (a) the practice of hilling cassava, (b) fertilizer, (c) land quality, (d) seed quality and availability of credit. At the same time, plowing, number of plants per hectare and weeding seemed to have no effect on yield. Only on sloping land does plowing appear to have a positive effect on yield per hectare. Seed piece placement, i.e., horizontal or slanted, did not seem to affect production on either sloping or flat land.

Production costs appear to be equal on both flat and sloping land with techniques currently used. Although land preparation and seeding costs are higher on sloping land than on flat, seed costs, weeding, fertilizer, and vigilance costs are lower.

3. Other studies in progress include an evaluation of cassava-starch plants in Colombia, and a detailed evaluation of cost components involved in cassava production.

**Agronomy and Germ Plasm Evaluation**

The germ plasm collection of approximately 2,800 cultivars is being catalogued. Some agronomic characters, under conditions at the CIAT farm, were noted at 9-10 months after planting on approximately 550 varieties in non-replicated three-row plots. Llanera was planted every fifteenth plot as a test variety.

Few varieties produced a higher yield than Llanera. Many varieties produced a greater total plant weight but had a less desirable ratio between roots and tops. Fresh weight harvest index (100 x root weight ÷ total plant weight = fresh weight harvest index) varied from less than 5 up to 78. The harvest index of Llanera (60-65) is greater than the average for most varieties tested (35-45). Preliminary analysis indicates that high yields are associated with a high harvest index. Some varieties with a particularly vigorous top growth and a low harvest index gave high yields (Table 1).

The collections with high harvest indices are highly variable, differing in branching, leaf type, root distribution and shape. Some of these lines are now being multiplied for further testing under other climatic conditions and cultural practices.

TABLE 1. **Fresh weight harvest index, root and top weight of selected Colombian cassava cultivars.**

| Collection No. | Fresh weight Harvest Index | Fresh weight per plant (kg) Roots | Aerial Parts |
|---|---|---|---|
| 3 | 7.3 | 0.5 | 6.3 |
| 2 | 32.7 | 3.9 | 8.0 |
| 36 | 33.8 | 4.8 | 9.4 |
| 9 | 37.1 | 5.6 | 9.5 |
| 12 | 38.7 | 5.5 | 8.7 |
| 73 | 43.5 | 5.4 | 7.0 |
| 81 | 50.0 | 6.6 | 6.6 |
| 71 | 54.0 | 6.8 | 5.8 |
| 35 | 56.4 | 7.0 | 5.4 |
| 22 | 59.6 | 5.3 | 2.6 |
| Llanera* | 60.0* | 4.9* | 3.2* |
| 68 | 75.0 | 5.1 | 1.7 |
| Ave. 121 cultivars | 42.5 | 3.9 | 5.3 |

* Mean of 8 plots.

Density and dry matter are commonly used to estimate starch without doing the detailed and time-consuming chemical analyses. Density was determined for individual roots from each of five Llanera plants harvested from fertilized and unfertilized soil (Table 2). The range in individual root density from a single plant was greater than the range in average densities between plants. Roots from unfertilized plants had a higher density than fertilized roots. The difference was small but significant at a 0.10 level.

Roots from Llanera plants grown on soil fertilized at two rates and an unfertilized soil were divided according to size by weight and analysed for density and dry matter (Table 3). Both density and dry matter in roots weighing more than 250 grams from the fertilized plots were essentially the same for all size classes. Roots of less than 250 grams were significantly lower (0.05 level) in density and dry matter than those larger.

Fertilizer application significantly lowered density of the roots produced.

TABLE 2. **Average Llanera root density per plant and range of density for individual roots harvest from fertilized and unfertilized plots.**

| Plant Nº | Density: Fertilized [1] Plant Average | Range in Individual roots | Not Fertilized Plant Average | Range in Individual roots |
|---|---|---|---|---|
| 1 | 1.087 | 1.068-1.104 | 1.103 | 1.080-1.111 |
| 2 | 1.079 | 1.069-1.095 | 1.093 | 1.086-1.102 |
| 3 | 1.089 | 1.076-1.103 | 1.094 | 1.064-1.121 |
| 4 | 1.087 | 1.081-1.095 | 1.107 | 1.103-1.118 |
| 5 | 1.087 | 1.078-1.095 | 1.092 | 1.072-1.114 |
| Average | 1.087* | | 1.098* | |

1. Fertilization rate of 60-60-120 kg of N, $P_2O_5$ and $K_2O$ respectively.

* Difference is significant at the 0.10 level.

Doctor Pierre Silvestre, France (left) and Dr. Efraim Hernandez X., Mexico, discuss cultivars from CIAT collection during a recent cassava conference.

Dry matter differences showed the same trend but this was not significant. The greater variation in dry matter is probably associated with sampling procedures. Approximately three kilograms of several roots were used for density analysis compared with only 50-250 gram samples for dry matter determination. The larger samples permitted an averaging of variability from several roots.

Root samples from more than 100 of the more desirable collections were taken to a small extracting unit to estimate the amount of "industrial" starch extracted by commercial systems presently used in Colombia. These facilities for extracting starch, locally called "ralladero", have a root capacity of two to three tons per day with simple, low cost, locally built equipment. In the extraction of starch, the roots are hand peeled, washed and then grated with a rotating rasp wheel driven by a small gasoline engine or electric motor. After grating, the pulp is put into a perforated rotating drum lined with a cloth screen. Water is added to the material as the drum rotates and the starch is washed out into a large tank while the fiber or pulp of the root is retained in the drum. After the suspended starch settles, the water is drained and the starch is sun-dried immediately or left to ferment in a tile-lined tank 15-30 days before sun drying. The starch, either fresh or fermented, is used by numerous small bakeries throughout the area for specialized bread and other products.

A comparison of starch extracted in the "commercial system" and the starch content as determined by using a conversion factor for either dry matter or density indicates the amount of starch obtained in processing was more closely predicted by conversion from density measurements than from dry matter evaluation using a "standard" conversion factor (Table 4). Cours's [1] conversion table for density provided a fairly accurate evaluation; however, extraction of starch from some cultivars is probably more difficult, resulting in variations from the predicated value, as is shown by sample numbers 57 and 24.

1. Cours, G. 1951. Le Manioc a Madagascar, Memoires de L'Institut Scientifique de Madagascar, Tome III, serie B., p. 337.

TABLE 3. **Effect of fertilizer and root size on cassava root density and dry matter.**

| Root size gms | High Density | High D.M. | Medium Density | Medium D.M. | None Density | None D.M. |
|---|---|---|---|---|---|---|
| | Fertilizer treatment [1] | | | | | |
| - 250 | 1.066 | 25.4 | 1.074 | 28.1 | 1.096 | 35.4 |
| 251- 500 | 1.089 | 30.5 | 1.079 | 33.7 | 1.094 | 30.6 |
| 501- 750 | 1.085 | 33.6 | 1.090 | 35.2 | 1.103 | 32.6 |
| 751- 1,000 | 1.087 | 32.8 | 1.092 | 32.1 | 1.096 | 37.6 |
| 1,000+ | 1.038 | 31.9 | 1.097 | 32.5 | 1.095 | 31.1 |
| Ave | 1.083 | 30.8 | 1.086 | 32.3 | 1.097 | 33.5 |

1 Fertilizer treatments:
High: 120-120-240 kg of N, $P_2O_5$ and $K_2O$ respectively per hectare applied preplant and incorporated.
Medium: 60-60-120 kg of N, $P_2O_5$ and $K_2O$ respectively per hectare applied preplant and incorporated.

Approximately 850 root samples were collected and prepared for laboratory analysis for nitrogen, the majority of the cultivars having a nitrogen content in a range of 0.08 to 0.56 percent. Llanera consistently is one of the highest in crude protein content with about 6 percent, although several other cultivars were found with intermediate to almost equal levels of nitrogen. Llanera, however, was the only cultivar which was agronomically satisfactory under the conditions tested. Analysis of additional cultivars is in progress together with studies on protein composition and feeding value.

## Entomology

Studies are underway on the identification, biology, distribution, economic importance, etc., of cassava pests. The preliminary review of world literature on cassava pests shows that there are about 100 species of arthropods producing different types of damages to cassava. From these species, 37 occur in Brazil and 17 in Colombia. The most important pests of cassava in Latin America are: **Erynnys ello** Man. (horn worm), **Carpolonchaea chalibea** Widem (shoot fly), **Coelosternus** spp. (stem borer) and **Mononychus planky** (spider mite).

Preliminary work on the shoot fly indicated that 15 percent bud damage represents a population threshold level of economic importance. Control is easily obtained by a single spray application when the level of damage is less than 15 percent. More chemical applications are needed when damage exceeds 15 percent. Differences in varietal susceptibility are shown through the high resistance of Llanera compared with other Colombian varieties.

Studies of the horn worm indicated that leaf shape could play an important role on the preference of the insect for oviposition. Two larva parasites, two predators and a bacterial disease have been found to check this pest under field conditions. Future work will involve evaluation of economic importance of various insect pests and the screening of insecticides to give emergency insect control along with the long range control through resistant varieties and biological control systems.

## Plant Pathology

**Quarantine:** A total of 705 cultivars from five countries was heat treated and observed at the ICA Tibaitata Experiment Station in Bogota before transfer to CIAT. Sixty came from Puerto Rico, 76 from Ecuador, 326 from Venezuela, 176 from Peru, and 67 from Mexico. The

TABLE 4. **Comparison of starch extracted by a "Ralladero" with percent calculated based on dry matter and density determinations for 10 cultivars of cassava.**

| Cultivar Nº | | Starch extracted by ralladero % | Dry Matter Basis | | Density Basis[2] | | |
|---|---|---|---|---|---|---|---|
| | | | Dry Matter % | Starch[1] % | Density % | Total Starch % | Industrial Starch % |
| M-Col | 10 | 25 | 43.8 | 37.0 | 1.162 | 32.6 | 27.4 |
| ,, | 19 | 25 | 42.6 | 35.8 | 1.142 | 28.1 | 22.3 |
| ,, | 24 | 14 | 40.3 | 33.5 | 1.151 | 30.1 | 24.5 |
| ,, | 39 | 23 | 43.0 | 37.2 | 1.144 | 28.5 | 22.7 |
| ,, | 41 | 23 | 41.2 | 35.4 | 1.146 | 29.0 | 23.3 |
| ,, | 57 | 9 | 46.4 | 39.6 | 1.158 | 31.7 | 26.4 |
| ,, | 75 | 25 | 43.3 | 36.5 | 1.138 | 27.1 | 21.1 |
| ,, | 80 | 13 | 35.6 | 28.8 | 1.107 | 19.7 | 12.7 |
| ,, | 103 | 8 | 29.0 | 22.2 | 1.105 | 19.3 | 12.3 |
| ,, | 110 | 15 | 37.7 | 31.9 | 1.109 | 20.2 | 13.3 |

1 Percent starch = percent dry matter - 6.8 (factor for peeled roots)
From Holleman, L. W., and A. Aten 1956. Processing of Cassava and Cassava Products in Rural Industries. F.A.O. Agricultural Development paper Nº 54, Rome, Italy, p. 82

2. From Cours, G. 1951. Le Manioc á Madagascar. Memoires de L'Institut Scientifique de Madagascar Tome III série B: p. 337.

clones from Peru were destroyed when common cassava mosaic was detected in some plants. A few clones from Venezuela were affected with bacterial disease and were also destroyed. The rest of the Venezuela collection was planted at the ICA Experiment Stations in Nataima, Espinal, and Palmira. Five wild cassava species from Venezuela, 14 cultivars of yams, and 40 sweet potato varieties were also quarantined in Tibaitata.

**Viability of Cuttings**: Cassava cuttings kept at 4º C for 29 days failed to germinate, while cuttings remained viable for 65 days when stored at room temperature with the cut ends protected with fungicide. Dipping the ends in wax extended viability to 85 days but the wax must be removed prior to planting or the cuttings will not germinate.

**Virus Diseases**: The common cassava mosaic virus was detected in some of the collection from Peru with the electron microscope. It is a flexous rod, 500 microns long and 15 microns wide (Fig 3). The symptoms in the plant and the morphology of the virus coincide with the common cassava mosaic present in Brazil. The African common mosaic was also compared by electron microscope studies with the American common mosaic. No virus particles were observed in ultra-thin sections or in the leaf dip of the African mosaic. Another difference between the two mosaics is the method of transmission. African common mosaic is white fly-transmitted, whereas the American mosaic does not have a known vector.

The high thermal-death point (70º C - 10 min) precludes a hot water treatment for control of American common mosaic; other methods must be sought.

**Bacterial Disease**: The bacterial disease was studied as a doctoral thesis through ICA-CIAT and the University of Wisconsin cooperation. Fifteen different isolates of the pathogen were collected in infected plantations from Brazil (Sao Paulo), Venezuela, and 10 different states of Colombia. It was found that the penetration of the pathogen was via stomata or injured tissue and that it induced symptoms of leaf spots, blight, dieback and wilting, depending on cultivar susceptibility. Spreading was mainly by raindrops splashing the bacterium from plant to plant or by using contaminated tools. Infections are spread from one crop to another through the use of infected cuttings.

More than 1300 different cultivars from the CIAT collection were inoculated with bacteria and 21 cultivars were found to be resistant/highly resistant to the organisms tested in accordance with a scale which rated the above mentioned symptoms. Cultivars 642, 647, 667, 1184, 1155, and 1079 showed the highest resistance. Leaf spot invasion did not occur in cultivars 647 and 667. No cultivars showed immunity.

Limited tests indicate the pathogen was able to survive for 5 1/2 months in necrosed stems, 2 1/2 months in diseased petioles, 35 days in necrosed leaves, 20 days in sandy-wet soil. These trials were conducted in a growth chamber maintained at 22º C and 70-80 percent relative humidity with an 800 foot-candle light intensity for 12-hour photoperiods. No infection occurred in plants grown on soil which had been artificially inoculated six months previously.

To identify and characterize the cassava bacteria, 26 biochemical and physiological tests were performed with 14 isolates of the cassava bacterium. The utilization of 19 carbohydrates and sugar derivates; 32 fatty acids, decarboxylic acids, hydroxy and other acids; 20 amino acids, 16 aromatic amino acids, amines and related compounds; and 15 nitrogenous substrates have been determined.

Serological studies showed that isolates of the cassava bacterium have a similar relationship when agglutination and agar-double diffusion tests were performed. They did not show any serological relationship with four isolates of **Erwinia chrysanthemi** pathotype seae, one isolate of **E. chrysanthemi,** two isolates of **E. caratovora,** nine isolates of **Pseudomonas solanacearum** (three representatives to each of the three races), one isolate of each of **Xanthomonas axonopodis, X. malvacearum, X. campestris, X. pruni,** and six non-pigmented xanthomona. No lysis was observed to represent isolates of the same species included above by an isolated bacteriophage and a **Bdellovibrio** sp. which showed specificity only to the bacterium isolates of cassava. Theoretically, both organisms could offer biological control for the cassava bacteria; evaluations have not been made up to the present.

In a test using 15 different chematherapeutants, the bacterium was resistant only to Penicillin (10 u g) and Macrodantin (100 u g). It was sensitive to dihydro-streptomycin, Novobiocin, Chloromycetin, Rifampicin, Bristaciclin, Rifamicin, Garamicin, and Neomycin.

**Fungi Diseases:** Phomopsis, an important disease of cassava caused by the fungus **Phoma** sp. or **Phyllosticta** sp., was found in the states of Cauca and Valle. Preliminary symptoms in young seedlings consist of wilting. Longitudinal section of infected plants showed dark brown streaking, leaves that have dark brown to black colored lesions and plants that present a die-back symptom somewhat similar to the bacterial disease. The difficulty of making the fungus sporulate in the laboratory was overcome through the use of artificial light, opening the way for massive screening of the cultivars in the germ plasm collection. At least two clones observed near Popayan (Cauca) under serious epiphytotic conditions were highly resistant.

**Anthracnose.** Necrosis and death of the stems were observed in the affected plants. The spores produced in the lesions were pinkish in color. The disease is caused by a **Gloeosporuim** sp.

**Glomerella** sp. Another cassava disease caused by **Glomerella** sp. showed black canker and white mycelium on the surface of those cankers.

**Ascochyta** sp. A disease characterized by concentric rings in the dark brown leaf spots was found in Caldas and Cauca. This disease may be caused by an

FIGURE 3. Particles of cassava mosaic virus found in Latin America taken by an electron microscope.

Bacterial infected cassava showing typical stem lesions and bacterial exudate from the green, immature stem or branch.

Typical symptoms of bacterial wilt in cassava. Younger, fully mature leaves wilted and dried green on erect petiols.

**Ascochyta** sp. Further studies for characterization of these diseases are planned, as well as the development of mass screening techniques for resistance.

## Weed Control

Little has been done in weed control. A thorough search of the literature yielded only seven specific references to weed control, many of them contradictory.

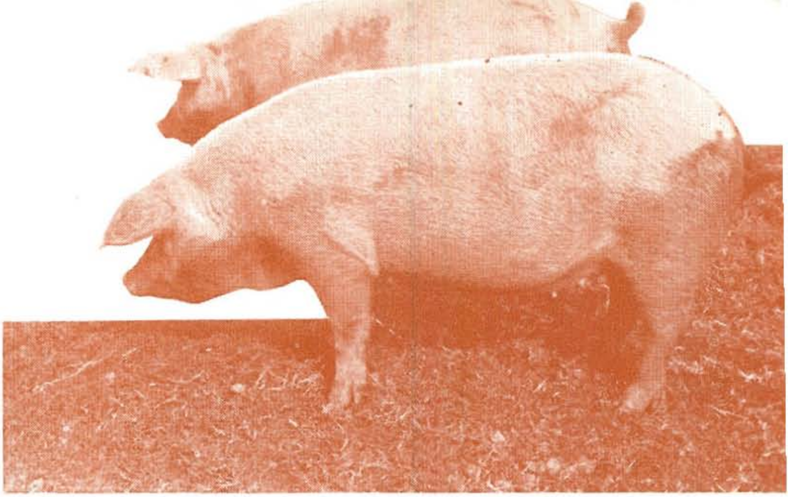
Preliminary results of a weed competition study in cooperation with ICA, Turipana, indicate that cassava must be kept weed-free at least 45 to 60 days to avoid competition losses.

Since little is known about chemical selectivity in cassava, plans are to screen a large number of herbicides at the potentially safe rates and two and four times these rates to determine selectivity and observe herbicide injury symptoms if they appear.

Because of the long growing cycle of cassava, integrated control is of great importance to obtain full season control. In the cultural practices experiments, effects such as row spacing and plant densities should be evaluated in terms of the competitive ability of cassava. These recommendations then must be incorporated with economical and feasible chemical and/or mechanical methods.

# Swine

## Production Systems



The Swine Program seeks to help increase pork production in the lowland tropics by emphasizing the identification and resolution of the major barriers limiting swine production and the training of persons for national swine production and research programs.

### Small Farm Production Systems

Most of the pigs in the tropics are produced in small herds on small or subsistence farms; level and efficiency of production are low. Pigs presently supply a readily available income for many people in the lowland tropics. With greater production efficiency the present swine population could produce greater income and amounts of animal protein with less feed.

A project to study ways to improve the efficiency of swine production on small farms has been launched on the north coast of Colombia. Also, initial efforts are concentrated in a locality representative of many such areas in the tropics. The factors which limit economic swine production and those which limit the introduction of technology and improved practices are being studied. The project initially emphasizes three phases:

1. Determination, through field survey, of the existing level and efficiency of production, husbandry practices, feeding systems, health problems and market systems to establish a base-reference point.

2. Introduction of improved practices specifically designed for local conditions to overcome factors identified as limiting production. Although a "package system" is envisioned, the practice will be introduced gradually as a "spiral" approach.

3. Future evaluation of the effect of the introduced systems on production and income.

The original data indicate an average of 11 pigs per farm. A herd usually includes a sow and 10 pigs, the ages ranging from birth to two years. The unimproved native pig (Zungo Pelado) predominates and, although litter size and reproductive capacity appear satisfactory (about eight pigs born per litter), growth rate is extremely slow. Pigs are marketed at 12 to 18 months of age, weighing about 60 kilograms.

Many factors appear to influence these low production levels, including deficient nutrition, heavy infestation of internal and external parasites, poor genetic stocks, and inadequate management.

Pigs normally roam the area for fallen fruit, worms, roots, sprouts, grass and other foods. When they return home, they are fed shelled common corn; if corn is scarce, the pigs get small quantities of cassava or yams. When avail-

**Swine production offers an opportunity to subsistence farmers of the lowland tropics where human diets are notoriously deficient in proteins and sources of income are very scarce. Both factors retard progress in these areas.**

able, farmers use rice bran as a supplement. Whey from home-made cheese is fed on some farms, as are small amounts or kitchen waste. Vitamins, minerals and protein are not commonly available, and where obtainable are seldom used because farmers do not appreciate their value or do not have the money to buy them.

Examination of fecal samples and autopsy of animals have identified parasites, including lungworms, roundworms, nodular worms, coccodia, cysticercus, and sarcoptic mange. Many animals exhibit a general syndrome of fatigue, accompanied by cough and nasal discharge, and many deaths result. The cause is not known.

There is little influence of improved breeding material, the majority of the pigs being characterized by wattles and lack of hair.

A uniform marketing system does not exist. Pigs are sold by the head to traveling buyers when cash is needed, and there is little knowledge of actual weight or market value.

### Training and Institutional Development

Eight animal scientists from Colombia, Ecuador, Mexico and the United States have received production and research training. One scientist is completing a master's degree thesis and another a doctorate in international animal science at the University of Illinois.

The production training program now being designed will consist of two parts. The first six months will be devoted to teaching and applying proven production procedures and practices. All trainees will complete this period of training which will be considered as adequate for extension agents and university personnel who will teach swine production. After completion of the initial training period, those involved in national research will receive additional training in experimental design, analysis of results and the preparation and presentation of extension and research material.

The training programs are of value only if those trained return to their countries to work within effective national institutions. Collaborative work with INIAP in Ecuador has been successful. The swine programs at Santo Domingo and Santa Catalina, developing rapidly, are contributing to the national industry. Two members of the Ecuadorian program will complete master's degrees in early 1972. Plans are to develop a third swine unit at the Boliche Station.

Efforts in 1971 helped initiate swine research and training facilities in Costa Rica, Bolivia and Peru. In Bolivia, there will be a production and teaching facility and herd at the "José Benjamín Burela" National College of Veterinary Medicine, Santa Cruz. In Peru, preliminary studies have been made for a swine research unit at the IVITA Station at Pucallpa. The program, supported by the University of San Marcos, will be initiated in 1972. Collaborative breeding and nutrition studies continued in ICA, Colombia, facilities.

**Feeds and Swine Feeding Systems**

Materials available for swine feeding in the tropics are diverse in type and quality. Energy sources presently available include maize, sorghum, sugar, molasses, cassava, bananas, plantains, yams, sweet potatoes and rice bran and polishings. Estimates of future rice production increases indicate that this grain may also be considered for use in swine rations.

**Cassava:** Cassava and cassava meal are a valuable energy source for swine. Although satisfactory results are obtained, analyses indicate that the presence or absence of some factor of factors influence the optimal use of this food. The nitrogen and glycoside fractions are being studied.

Studies by CIAT personnel at the Universidad del Valle indicate that approximately 40 percent of the nitrogen present in cassava is protein nitrogen, the remainder being non-protein nitrogen. Fernando Calderón, a Costa Rican student at the University of Florida, is making a more detailed evaluation of the nitrogen fraction and will continue protein evaluation studies at CIAT in 1972 as a thesis project.

Swine and poultry studies demonstrated that methionine supplementation of diets containing high levels of cassava significantly improves growth and feed efficiency. Although cassava is deficient in methionine, these results might not be expected in view of other results with sugar based diets which indicate that the methionine level of soybean meal is adequate for optimum growth when used as the only source of protein. However, additional methionine is necessary to support the best gains when cassava meal prepared from the Llanera variety is used as the major energy source.

This need for additional methionine may be the result of inactivation of the methionine by the hydrocyanic acid (HCN) present in the cassava. Although definitive published results are not available, some information related to the cassava-eating population of Africa indicates that thiocyanates are present in the blood and urine of cassava-consuming humans, and goiter develops after long periods of cassava consumption. If the low level of HCN present in the cooked cassava combines in the liver with the sulfur from methionine and cystine to form a thiocyanate, this would explain both the need for supplemental methionine and the development of goiter.

Thiocyanate formation in rats fed cassava with high levels of HCN is being measured. Urine and blood serum samples are being analyzed for the presence of thiocyanates, and nerve and thyroid tissue will be studied histopathologically to assess any morphological changes from HCN toxicity. Diets containing sugar or dried cassava are included as controls for measuring toxic effects of fresh cassava which is high in HCN.

Preliminary results indicate that the

consumption of cassava containing high or low levels of HCN will definitely increase the normal output of thiocyanates by the rat. The liver appears to be the site of HCN detoxification. Within this organ the $CN^-$ of hydrocyanic acid combines with sulfur and probably iodine and potassium to form thiocyanates. As the level of thiocyanates builds up in the blood stream, it is excreted by the kidney and appears in the urine.

The normal level of thiocyanate excretion by rats on diets containing no HCN is approximately 0.11 mg (measured as potassium thiocyanate) per day. Similar groups of rats fed diets containing dried cassava meal prepared from Llanera roots containing low levels of HCN excreted 0.48 mg per day. When fresh cassava containing high levels of HCN was fed to rats, the level of thiocyanate excretion was increased to 3.70 mg or 8 times the dried cassava diets and 33 times that of the control diet based on sucrose.

The total significance of thiocyanate production and excretion based on diets containing HCN is not yet known. But from previous reports and these results, it does appear that HCN **per se** can increase sulfur amino acid requirements (methionine and cystine) of non-ruminant animals by deactivating the amino acid by combining with the sulfur portion. Thiocyanates thus formed can further interfere with iodine uptake through the formation of iodine compounds and, therefore, play an important role in goiter production.

**Bananas**: Collaborative research with INIAP in Ecuador has demonstrated the usefulness of bananas as a source for growing-finishing, gestation and lactation. Although fresh, ripe bananas are an excellent source of energy for growing-finishing and gestation, they cannot be used effectively during lactation, and, therefore, dried green banana meal must be used to supply the major portion of the ration. Dried ripe bananas are not commonly used because of drying difficulties.

Ripe bananas supported faster and more efficient and economical gains than green bananas. Other studies focus on the factors responsible for these differences in feeding value because of differences in ripeness. Pair feeding studies with INIAP (Santa Catalina, Ecuador) demonstrate that the feeding value of both ripe and green bananas are similar if the pig consumes equal quantities of each banana. Similar groups of pigs were daily fed equal quantities of either ripe or green bananas along with equal quantities of a protein supplement. After 28 days, pig gains and efficiency of feed conversion were not different, indicating that the poor performance of pigs fed bananas in previous studies was due basically to the low level of banana consumption caused by the poor palatability of the green bananas.

The poor palatability of green bananas is apparently associated with the presence of active tannins. Although the total concentration of tannins, or "vegetable tannates", does not vary between the green and ripe banana, during the ripening process the level of active tannins, which imparts a bitter taste to the banana, decreases progressively during ripening. Although it is not economically feasible in a commercial operation, removal of the green banana peeling will reduce the active tannins level as the active tannins level is higher in the peel than in the pulp.

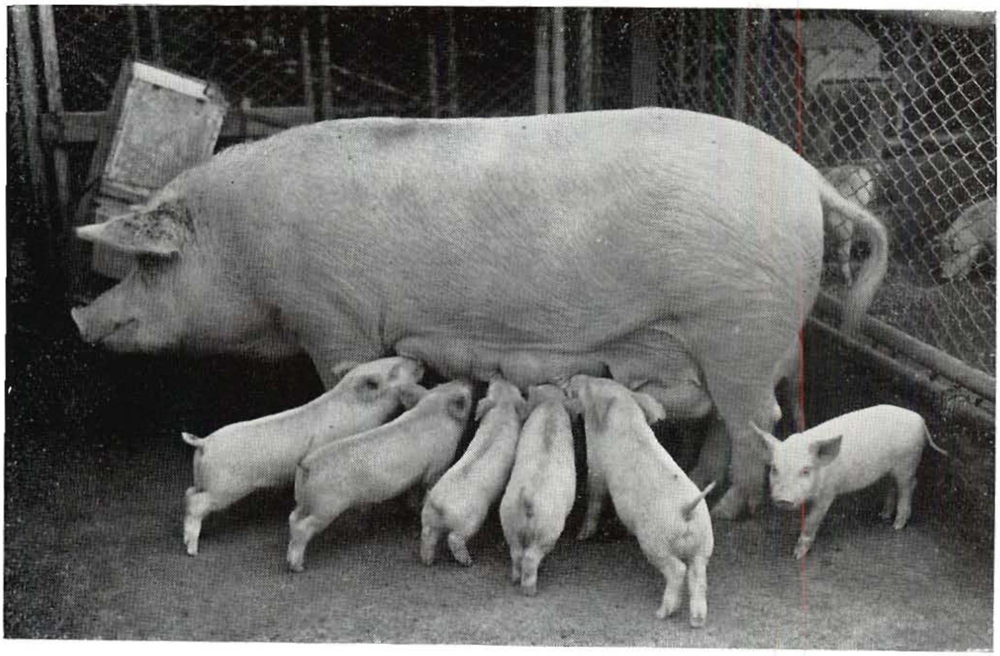
More detailed studies will determine the digestibility of the component parts (protein, fiber, fat and nitrogen-free extract) and to measure the digestible and metabolizable energy value of ripe and green bananas both as the fresh fruit and as dried meal. These data are being obtained as a thesis project by a CIAT research scholar from Ecuador.

**Maize**: Experience has demonstrated the value of normal maize and the level of supplemental protein necessary for efficient use of maize. Substantial quantities of supplemental protein are essential for proper utilization during all phases of the pig's life cycle. However, similar experiments with opaque-2 maize have shown that this grain can provide sufficient protein during all phases of the life-cycle except for the pre-weaning and growing periods. Both periods require supplemental protein for efficient use of the opaque-2 maize diets. Pigs at 22-25 kg make optimal gains on opaque-2 maize-based diets containing only 12 percent protein; at weaning weights less than 18 to 20 kg, however, the 12 percent protein diets support slightly less rapid growth than a standard 16 percent protein control diet. Studies indicate that an opaque-2 maize-based diet containing 13 percent protein will produce gains not different from the control but inferior to similar opaque-2 maize diets containing 14 percent protein. Pigs fed 14 percent protein diets based on opaque-2 maize-soybean meal gained 8 percent more rapidly than those fed 16 percent protein normal corn-soybean diets.

A pilot study with female rats is being conducted to determine what effect a life-cycle feeding of normal corn, opaque-2 corn and a control corn-soya diet have on growth and reproduction and on the growth characteristics of their offspring. Growth rates during the growing period confirm previously reported results which indicate that growth is slow on common maize, improves with opaque-2 maize, but is superior with 15 percent protein control.

Available reproductive data indicate that rats fed any of the three experimental diets will cycle and produce litters. When opaque-2 corn was used as the only source of protein, normal breeding and gestation with litters were similar to those obtained from the control (15 percent protein) rats. Rats fed opaque-2 corn throughout growth and breeding could not support a normal lactation (litters with low weaning weights) because the opaque-2 corn was nutritionally inadequate.

When common corn replaced opaque-2 corn in the diet, all the females cycled,



**Large healthy litters are the result of production systems that combine adequate nutrition, breeding stock and proper management with sanitation and disease control.**

were bred, and produced litters. However, the litters were small in number and weight, and survival poor.

If similar results are obtained in pigs as in rats, the recommended use of opaque-2 corn in swine rations will be drastically affected. As previously reported, results obtained from studies conducted at different stages of the life-cycle of the pig indicate that opaque-2 corn alone is adequate for the finishing, gestation and lactation periods. However, these preliminary rat studies appear to indicate that although in isolated periods of either gestation, lactation or finishing the opaque-2 corn is adequate, it may not be adequate if used as the only source of protein during consecutive and continuous periods of the life-cycle.

The soft, lightweight kernels that are characteristic of opaque-2 maize prevent or reduce widespread acceptance for human food and cause storage problems. Studies have been made with the maize program to evaluate crystalline selections from commercial opaque-2 maize. Although results are promising, long term studies will be required to produce, evaluate and understand the inheritance of these crystalline characteristics.

In collaboration with ICA, seven double cross hybrids containing the floury-2 genes or both floury-2 and opaque-2 genes and eight floury-2 lines have been biologically evaluated. Results to date indicate that the nutritional value of the floury-2 crosses and lines is inferior to opaque-2 hybrids.

**Triticale:** In collaboration with CIMMYT in Mexico, three lines of triticale were tested for nutritive value and compared to methionine-supplemented casein and Colombian opaque-2 corn. When fed to rats on an isometric basis, the higher protein triticale supported faster gains than opaque-2 corn and gains only slightly inferior to those produced by the control (10 percent protein) casein diet. When compared on an equal protein basis, all three triticales were inferior to casein and also inferior to the opaque-2 corn diet that contained slightly less protein. The efficiency of protein utilization (PER) was less than 50 percent of the casein diet and only about 69 percent of the opaque-2 corn. These data (Table 1) indicate that a kilo of triticale has a higher

TABLE 1. **Protein values of triticale[1], opaque-2 maize and casein.**

| Diet | Average Daily gain, grams | Average Daily Feed, grams | Feed/ Gain | Protein Efficiency Ratio (PER) |
|---|---|---|---|---|
| 1. Control (Casein & meth.), 10% | 3.41 | 8.88 | 2.03 | 3.82 |
| 2. Opaque-2 Maize, 8.31% | 2.20 | 9.80 | 4.42 | 2.74 |
| 3. Triticale-24, 10% | 1.35 | 7.43 | 5.55 | 1.80 |
| 4. Triticale-63 10% | 1.28 | 7.22 | 5.66 | 1.78 |
| 5. Triticale-106, 10% | 1.57 | 8.05 | 5.27 | 1.94 |
| 6. Triticale-24, 16.56% | 3.20 | 10.52 | 3.30 | 1.83 |
| 7. Triticale-63, 17.71% | 3.00 | 11.11 | 3.47 | 1.63 |
| 8. Triticale-106, 14.72% | 2.69 | 10.35 | 3.82 | 1.78 |

1. The analysed crude protein content of these three lines of triticale were: Triticale-24, 18%; Triticale-63, 19.25%; Triticale-106, 16.0%.

TABLE 2. **Effect of germination and cooking on nutritive value of cowpeas for growing swine.**

| Treatments | Average Daily Gain (Kg) | Average Daily Feed (Kg) | Feed/ Gain Ratio |
|---|---|---|---|
| 1. Control-Maize + Soya | .799[a] | 2.44[a] | 2.53[a] |
| 2. Crude Cowpeas | .551[bc] | 2.01[bcd] | 3.42[d] |
| 3. Germinated Cowpeas | .498[c] | 1.97[cd] | 3.45[d] |
| 4. Cooked Cowpeas | .816[a] | 2.39[ab] | 2.50[a] |
| 5. Crude Cowpeas + Meth. | .483[c] | 1.71[d] | 3.09[c] |
| 6. Germinated Cowpeas + Meth. | .649[b] | 2.03[bcd] | 2.70[b] |
| 7. Cooked Cowpeas + Meth. | .815[a] | 2.28[abc] | 2.43[a] |

nutritive value than a kilo of opaque-2 corn; however, one gram of protein from triticale has only about 69 percent the value of one gram of protein from opaque-2 corn.

**Cowpeas**: If swine production is to be made efficient, economically attractive and readily available, economical sources of supplemental protein must be found. Grain legumes appear to offer the most immediate opportunity for both animal and human food. Previous pilot studies with rats have demonstrated that some grain legumes provide a fair supply of the amino acids needed to supplement the diet; however, most grain legumes have two limiting factors associated with their use as feed for non-ruminant animals. These are: (1) inhibitors which limit the digestibility and release of amino acids in the upper levels of the gastrointestinal tract, and (2) a deficient level of the sulfur-containing amino acids, methionine and cystine. Although the factors are listed separately, they are interrelated, with the inhibitors limiting the efficient release and utilization of the sulfur amino acids.

Studies to determine the most efficient and economical processing method—soaking, germination and cooking—that will supply a satisfactory product are underway. Soaking does little to reduce the inhibitors; germination appears to reduce the toxicity of the inhibitors in cowpeas but results are inconsistent. When fed to growing pigs, black-eyed cowpeas that had been allowed to germinate and then dried at 60°C until the moisture content was reduced to 10 to 12 percent failed to support growth even at a rate obtained with crude, unprocessed cowpeas.

However, it appears (Table 2) that the drying process may have destroyed some of the sulfur amino acids as the addition of methionine to the germinated-dried cowpea diets improved pig growth to a level superior to that obtained with similar additions of methionine to the crude cowpea diets. Cooked cowpeas provided a protein that was well used by the pig even when it was the only source of protein. Growth rates and feed conversion of pigs fed diets based on cooked cowpeas as the protein source were similar to those of pigs fed standard control diets based on corn and soybean meal.

In the pig studies, cowpeas alone supplied all the protein. Preliminary studies with rats indicate that germinated cowpeas supplemented with 0.05% DL-methionine adequately supplement diets based on opaque-2 corn and, in fact, promote growth and feed conversion efficiency not different than that produced by soybean meal.

This second limiting factor, deficiency of the sulfur amino acids, has been studied in collaboration with a doctoral student from Purdue University working at ICA and the Universidad del Valle. Nutritive value can be determined by roughly screening the sulfur content of beans (**Phaseolus**). After chemical analysis to determine protein and total sulfur, diets were prepared from beans containing different levels of total sulfur. When these diets were fed to growing rats, it was not possible to predict precisely the protein quality on the basis of their protein and total sulfur contents, but it was possible to separate those with low from those with high nutritive value. More precise separations based on total sulfur content are probably not possible because of differences in ratios of methionine to cystine. It is known that cystine can be used to replace only a proportion (40-50 percent) of the methionine requirement. But if the cystine content is greater than the methionine content, then that surplus of cystine over methionine is of no value to the animal.

Varieties of cowpeas have been analysed for crude protein and sulfur. These analyses (Table 3) indicate that there is a range of crude protein in the 141 varieties from 18.70 to 29.82 percent and a range of sulfur expressed as percentage of protein from 0.61 to 1.43. Through selection based on protein and sulfur content and screening for nutritional value, it may be possible to obtain a cowpea that will supply adequate sulfur amino acids for pigs and humans.

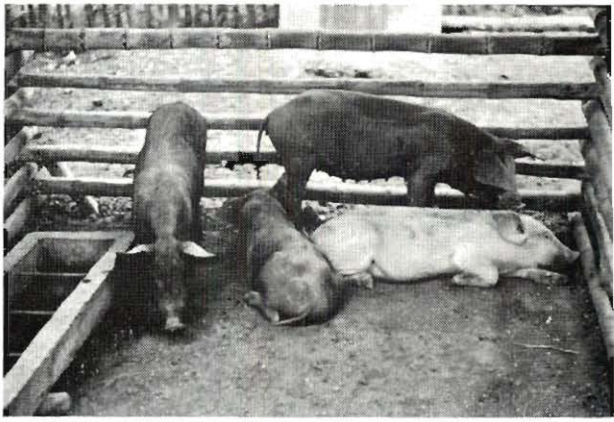
## Agricultural Economics

The work carried out by the agricultural economists has been integrated with the swine nutrition studies. A model was developed to estimate the economic feasibility of replacing one feed with another in life-cycle swine diets.

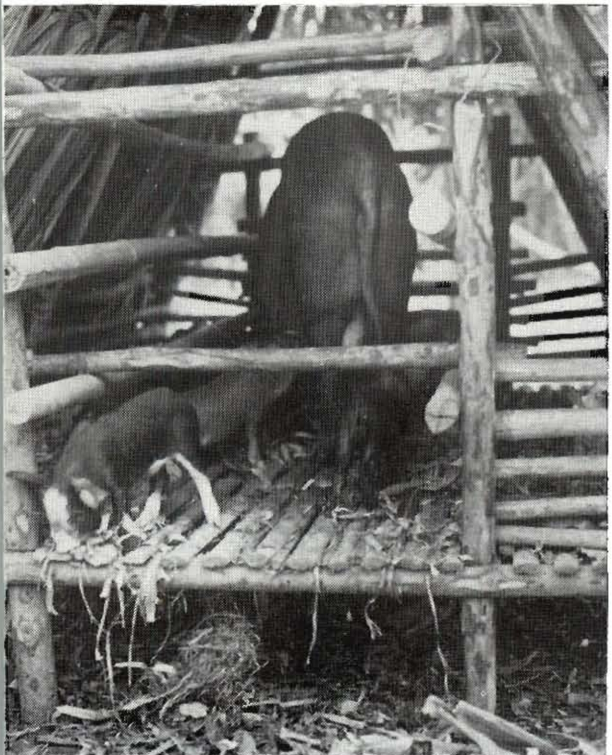
A research project to determine the major bottlenecks in swine production and marketing in two regions of Colom-

TABLE 3. **Distribution and range of crude protein and sulfur values for 141 varieties of cowpeas.**

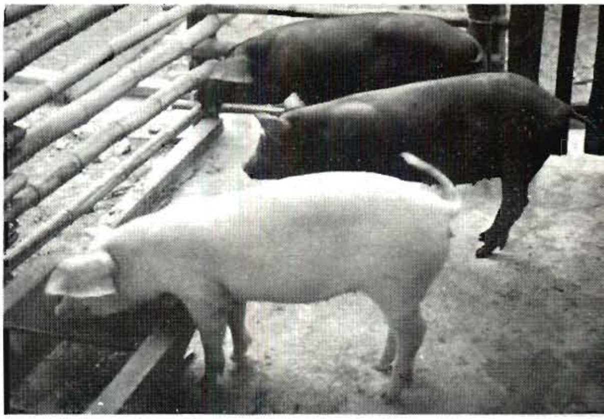
| Protein | | Sulfur | |
|---|---|---|---|
| Range % | Nº | Range (% of Protein) | Nº |
| 18-19 | 1 | .60- .70 | 18 |
| 19-20 | 1 | .70- .80 | 54 |
| 20-21 | 2 | .80- .90 | 44 |
| 21-22 | 11 | .90-1.00 | 17 |
| 22-23 | 17 | 1.00-1.10 | 6 |
| 23-24 | 25 | 1.10-1.20 | 0 |
| 24-25 | 30 | 1.20-1.30 | 1 |
| 25-26 | 18 | 1.30-1.40 | 0 |
| 26-27 | 21 | 1.40-1.50 | 1 |
| 27-28 | 7 | | |
| 28-29 | 6 | | 141 |
| 29-30 | 2 | | |
| | 141 | | |



Practical, low cost farrowing stalls built with local materials reduce pig losses on small subsistence farms.



On-the-farm demonstrations clearly indicate to subsistence farmers the need for proper feeding, management and disease and parasite control.



bia is in progress. Finally, a preliminary study to determine the economic feasibility of producing swine in the region of Pucallpa, Peru, is in progress.

**Opaque-2 Maize for Swine.** A study was made of the economic feasibility of replacing common maize by opaque-2 maize in maize-soybean oil meal diets given various prices of common maize, opaque-2 maize and soybean oil meal. Basic nutritional data were obtained from the swine nutrition studies. The analysis was divided into four parts on the basis of the nutritional requirements during the life cycle: gestation, lactation, growing, and finishing. A mathematical model was developed to estimate the relative net returns using diets of opaque-2 and common maize.

If the price of opaque-2 maize is equal to that of common maize, it appears profitable for the farmer to replace the common maize-soybean oil meal diet by an opaque-2 maize diet during gestation and lactation, when the price of soybean oil meal is above that of common maize. If the price of soybean oil meal is more than 120 percent of that of common maize, opaque-2 maize can also be used during the finishing cycle (50-90 kg). It does not appear profitable to replace common maize and soybean oil meal by opaque-2 maize during the growing cycle.

Opaque-2 maize yields approximately 10 percent less than the best common hybrid in Colombia. Assuming a 10 percent price differential, it would be profitable to replace a common maize-soybean oil meal diet by an opaque-2 diet during gestation, lactation and finishing if the price of soybean oil meal is more than 138, 150 and 180 percent of the price of common maize, respectively.

It was found that Latin American swine producers who do not use any protein supplements in the swine diets could greatly enhance the net return by replacing the present diets with an opaque-2 diet during the whole swine life cycle.

**Swine Production and Marketing in Colombia.** The Latin American domestic demand for meats is increasing rapidly. In a number of countries the price of pork is high relative to that of beef. Pork production is increasing at a moderate rate, and a research project is underway to determine the major reasons for the slow production increase. The project is a case study of two regions of Colombia: one is believed to use a relatively high level of technology and has easy access to a major market; the other uses low levels of technology and does not have easy access to a major market. Basic information is being gathered from producers and marketing agencies on management and marketing practices, and a detailed economic analysis of the production and marketing system will be carried out to identify major economic bottlenecks and to suggest improvements in the system.

**Swine Production in the Pucallpa Region, Peru.** This study forms a modest contribution to the national efforts to develop the rain forest region. The major economic problems associated with large production expansions in the region are the cost of transportation and the risk associated with storage and transportation.

## Animal Health

Isolated identification has been made of many diseases and parasites in the swine population in Latin America, but no systematic study has determined the economically important diseases of the tropical region. For 1972, 25 percent of the effort of the animal health program will be dedicated to swine. A systematic survey will be made of existing swine diseases to determine those of economic importance as a basis for establishing effective control systems.

A study of foot and mouth disease was initiated as part of the requirement for a doctoral thesis. The emphasis in this year-long study is on the pathology of this disease in swine infested by different routes.

# Rice

## Production Systems

Adoption in Latin America of the new high-yielding varieties (HYV) of rice reached significant levels in 1971. Mexico, Central America, Cuba, Colombia, Venezuela, Ecuador, and Peru have more than 25 percent of their areas in the HYV. Approximately 500,000 has were grown, representing about one-third of the total area excluding Brazil, where adoption has been minimal.

Most of the HYV have been in IR8. In Colombia the area planted to IR8 rose from 0.5 percent in the second crop of 1968 to 37.5 percent in the second crop of 1970. Costa Rica, with about 70 percent of its area in IR8, suffered a severe epidemic of rice blast in 1970, illustrating the dangers of genetic vulnerability when large areas are planted to one or a few related varieties.

Yields have risen parallel to the adoption of IR8. In the irrigated areas of Colombia they have increased from 3 ton/ha in 1966 to 4.9 ton/ha in 1970. As a result of increased production, the area in irrigated rice has remained relatively constant, while the upland rice area is declining rapidly.

CICA 4 AND IR22

CICA 4, developed cooperatively by CIAT and ICA, was released for commercial use in early 1971, along with IR22 which was named and released by IRRI in 1969. (See 1970 report for descriptions of CICA 4 and IR22.) ICA in Colombia provided foundation seed for farm plantings of 350 has of certified seed of CICA 4 and 250 has of IR22 during the first crop of 1971. The best yield data available indicate that CICA 4 averaged about 7.0 ton/ha and IR22 about 6.5 ton/ha on farms in various areas of the country. The production from these seed fields is sufficient to plant approximately 30,000 has in late 1971 and early 1972.

CIAT distributed 6.3 tons of CICA 4 in Colombia, mostly in units of 100 kilos, to evaluate further its yielding ability in areas not covered by the ICA seed multiplication program. Of this, 1,400 kg of CICA 4 were donated to ICA for free distribution to farmers in upland and otherwise marginal areas. Similarly, CIAT distributed 3,600 kilos of IR22 in Colombia. The yields reported from this seed provided by CIAT were similar to those given above.

In addition, CIAT sent 4,769 kilos of CICA 4 and 1,965 kilos of IR22 to 34 countries with nearly all of the seed dispatched to Latin America. Seed requests of one to five kilos were sent free of charge. Larger shipments, to a maximum of 300 kilos, were sent air freight collect with no charge for the seed. At this time, the few yield results reported from other countries confirm the experience in Colombia.

CICA 4 has been multiplied on a large scale in Ecuador for distribution locally, where it was renamed INIAP 6. It is known as Advance 72 in the Dominican Republic. IR22 was renamed INIAP 2 in Ecuador. The National Rice Program of Peru is presently multiplying the variety Nylamp, selected from a segregation population provided by CIAT. Nylamp comes from the same cross as CICA 4, and the two varieties are similar. Large stocks of Nylamp will be distributed to Peruvian farmers in 1972.

The massive international multiplication and testing of CICA 4 and IR22 in 1971 allowed a more detailed appreciation of their varietal advantages and disadvantages. IR22 and a closely related selection were badly hit by blast in Central America. CICA 4 has remained resistant to date but will probably become susceptible in the near future. The grain appearance of IR22 is widely accepted and is slightly superior to that of CICA 4. Both meet local preference for cooking quality. CICA 4 tolerates moderately low water and air temperatures whereas IR22 does not. CICA 4 has performed well under upland conditions when rainfall is not critically limiting. Both varieties are moderately susceptible to shattering, and farmers are cautioned to reduce speed of the pickup reels and to harvest at moisture contents above 22 percent. Both varieties will be significant in those areas where they have been adequately tested, but they are considered transitory, to be replaced rapidly with new, superior types.

## SEMINAR ON RICE POLICIES

Some 200 representatives of 23 countries met in Cali, Colombia, September 10-14, 1971, the central focus being the opportunities and implications associated with the introduction of new, high-yielding rice varieties in Latin America.

Many of these new rices have emerged from country programs, while others, such as CICA 4 and IR22, were developed through cooperative efforts of the International Rice Research Institute, the Centro Internacional de Agricultura Tropical, and the Instituto Colombiano Agropecuario.

Significantly, and indicative of the mounting interest in rice in Latin America, nearly 80 percent of the participants came at their own or the expense of their organizations.

They first learned about the new rices, the conditions necessary for their successful production, and the possible economic implications of increased rice supplies. Then, in small discussion groups, they analyzed rice production, marketing, and consumption data for specific countries. They explored the possible consequences of various policies and identified factors to be investigated further upon returning to their countries.

It was the purpose of this seminar to provide opportunities for decision makers to expand their horizons, so that they can make better policy decisions. More specifically, it was to indicate ways and means by which rice productivity increases may be achieved on a broad scale, and in such a way that these increases in productivity may benefit in terms of improved real incomes and diets the greatest number of persons in each country.

The typical Latin American diet is relatively high in calories but low in proteins, particularly those of high quality. Although rice has slightly less total protein than the other two important grains, maize and wheat, the quality of its protein is excellent. Hence, nutrition could be improved greatly if it were possible to substitute rice for a substantial part of the low protein plantain and/or cassava in the typical diet. Such high rice diets would provide sufficient protein for both adults and children. Therefore, in terms of human nutrition and well being, **increased rice production could play a vital role in the food economy of Latin America.**

**Visitors attending rice policy conference inspect rice variety experiment.**

Experiences in Asia and Central America clearly indicate that the obtaining of maximum benefits from the introduction of new high-yielding semi-dwarf rice varieties depends upon the development of coherent and complete action programs. Possibly the best way to understand this is to consider the various steps taken by countries that were successful with their rice action programs.

Such a program for an individual country involves at least the following steps; in some countries additional ones will be required because of unique circumstances.

1. In order that the country program can realize the benefits of this increased production and reduced cost, it will be essential to provide rice growers with adequate supplies of locally adapted varieties and inputs as well as appropriate cultural practices. Provision for the multiplication and distribution of high quality seed is essential; in some cases this can be left to private firms, in others, some mixture of government and private enterprise may be best.

2. Along with the improved adapted varieties, technical information on the growing of these new varieties should be provided if their potential is to be realized. This will require a well developed technically competent group of rice production specialists. Their services will have to be combined with adequate supplies of appropriate inputs such as fertilizer, chemicals, and machinery. These inputs should be made available to all producers at reasonable prices, in the right amounts and at the right time and place. But the concomitant benefits of increased production

depend upon an adequate marketing system involving two essential components, physical and financial. There are the physical issues: Specifically, adequate transport facilities are needed between farm and mill and storage, and final market. There is the necessity for adequate drying, storage, and milling facilities. These critical factors will determine the final quality of the rice available for sale. Spoilage and losses will occur if drying and storage facilities are inadequate, and a favorable percentage of unbroken long grain rice will only be possible if modern rice milling equipment is used.

3. Prior to the production of these quantities of rice, decisions will have to be made as to the proposed final disposition of it. Some Latin American countries will be able to maintain their exports of rice, and some will be able to enter the export market for the first time, if they follow aggressive policies leading to low cost production of a good quality rice. Current trends, however, suggest that this will be difficult to achieve, in the face of declines in world prices that are expected to result as exporting nations increase their production and importing countries achieve self-sufficiency. It may be expected, therefore, that the typical Latin American country will produce primarily for its own domestic market.

**The levee divides the varieties IR22 on the left and CICA 4 on the right in nitrogen fertilization experiments.**

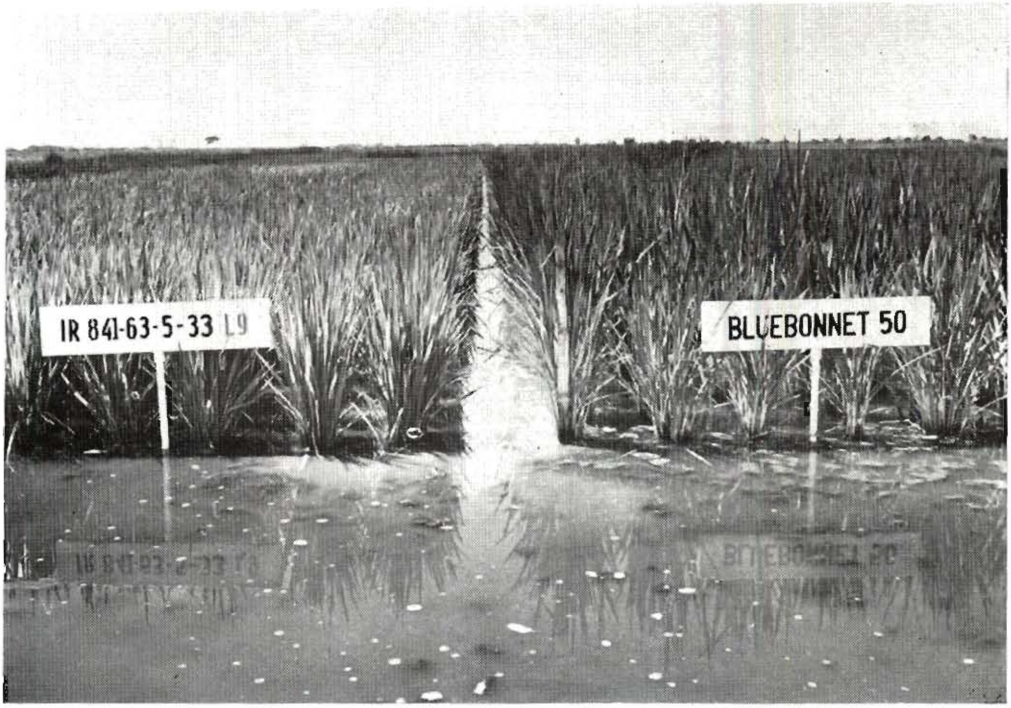
## BREEDING

**Crosses.** A total of 69 new crosses was made in 1971, bringing the total since 1967 to 581. All 1970 crosses involved the varieties Tetep, Mamoriaka, C46-15, and Dissi Hatif, which are suspected to have generalized resistance to rice blast. Thirty-three of the new crosses involving these parents were backcrosses to high quality, dwarf parents giving a total of 2,667 $F_1$ plants. Other crosses involving $F_1$ (dwarf) x blast resistant parents produced 3,470 $F_1$ seeds. The crossing program is concentrating on blast resistance now that earlier crosses have provided vast amounts of segregating material having superior plant type, grain characteristics, and resistance to Sogata.

**Nurseries.** Plantings of breeding material were made during 1970 on the ICA experiment station in Palmira in April, May, July, August, November, and December. These included more than 17,000 pedigree rows ($F_3$ to $F_8$) that were evaluated thoroughly for grain and plant traits.

Eleven $F_2$ single cross populations of 4,000 to 8,000 plants each were grown and selected. These were from crosses of high quality dwarfs and the varieties mentioned previously as having generalized resistance to blast.

A large pedigree nursery of $F_3$ lines from crosses of dwarfs and Colombia 1, a local variety which has maintained its blast resistance in hundreds of tests, was evaluated for blast resistance combined with dwarfism and acceptable grain. Few useful plants were found. The same single crosses backcrossed to the dwarf parent were evaluated in 1,010 $F_2$ families having about 200 plants each. About 50 percent of the families were susceptible to blast, and were discarded. The remainder, carrying resistance to blast, had excellent combinations of resistance, plant type and quality, and produced approximately 7,000 selections.




**The new rice selections with improved plant types are compared with the traditional variety Bluebonnet 50 in variety trials.**

This $F_3$ material appears so promising that bulk populations were sent to seven locations in six countries for local selections and evaluation. The observation that single crosses did not result in useful $F_3$ lines, whereas backcrosses to the dwarf parent produced excellent $F_2$ segregates, illustrates the need to concentrate on dwarf traits and rapidly eliminate the undersirable plant and grain characteristics of the blast resistant parents.

A number of excellent $F_6$ lines from crosses of IR930, IR579, IR532, and IR622 selections combine all desired traits except blast resistance. About 360 of these were simultaneously planted in both $F_6$ rows and in observational plots and were sent to other countries for wider evaluations. It is expected that one or more of these will become a named variety as a further improvement on IR8, IR22, and CICA 4. There is urgent need to develop a range of improved varieties even though they are all potentially susceptible to blast. Until generalized resistance to blast is bred into superior backgrounds, farmers must have a choice of several potentially susceptible varieties as the blast organism adapts itself to existing varieties.

In summary, nearly all material in the program is dwarf, has excellent milling and cooking quality, is early in maturity and has good resistance to Sogata feeding. Blast resistance, now the major objective of the program, continues to be a difficult breeding problem. Promising $F_2$ and $F_3$ material must be rigorously observed for a few more generations before firm conclusions can be drawn.

**Yield Trials.** A total of 119 lines were evaluated in June. These included selections from the earliest crosses made in Palmira and several advanced lines from IRRI. Many plots yielded from 6 to 9 ton/ha while local check varieties produced 2 to 4 ton/ha. Nevertheless, the majority has undesirable grain and/or late maturity, and only 26 lines were retained. In December, these 26 lines were included in a trial of 390 entries, many of which seem especially oustanding.

The 1970 Annual Report presented preliminary yields of the selections IR665-23-3-1-1B made in Palmira. Seeds of selected plants were processed in a test-tube miller, and seeds of 120 had minimum grain breakage. These were multiplied, and of 80 single rows harvested, 20 ranged from 51 to 62 percent head rice compared to 37 percent for the original line and 52 percent for Bluebonnet 50. These 20 selections were replanted in multiplication plots in November to increase seed rapidly. Uniform selections that maintain a high milling recovery will be bulked in early 1972 for extensive international evaluation.

## RICE AGRONOMY

The major objectives of the agronomy experiments during 1971 were:

1. Improvement in nitrogen efficiency through studies of rates and times of application.
2. Improvement in nitrogen response through better water management practices, and
3. Evaluation of new varieties and promising genetic lines by comparison with traditional varieties.

Because all of the above experiments developed zinc deficiency symptoms, a fourth objective had to be added:

**Top-dressing CICA 4 with urea.**

TABLE 1. **The effect of delayed flooding after fertilization on nitrogen response.**

| Water treatment as related to N. applications | Yield Kg/ha |
|---|---|
| Flooded same day | 7,350 |
| Flooded in 3 days | 6.726 |
| Flooded in 6 days | 6 289 |
| Flooded in 9 days | 5,940 |

4. Determine best sources, rates and methods of application of zinc to improve rice yields.

## RATE AND TIMING OF NITROGEN APPLICATION

Two experiments, using CICA 4 and IR22, were affected by zinc deficiency and could not be completely controlled by foliar sprays or by light applications of zinc sulfate. The CICA 4 experiment was so seriously affected that it had to be discarded. The results of the IR22 experiment showed that there was only a slight response to nitrogen in this experiment. Fifty kg N/ha applied 25 days after seeding produced practically the same yields as higher amounts applied in one, two or three applications. Soils on the CIAT farm appear to have the capacity to supply the major part of the nitrogen requirement.

## EFFECT OF WATER MANAGEMENT ON NITROGEN RESPONSE

In one experiment, flooding was delayed from 0 to 9 days after the application of 100 kg/ha of nitrogen on a drained soil. The results are shown in Table 1.

The data indicate that delayed flooding resulted in nitrogen losses and that higher yields were obtained by flooding as soon as possible after nitrogen applications.

## VARIETY TRIALS

CICA 4 and IR22 were compared with the traditional varieties now being grown in Colombia and a number of other countries in Central and South America. Some new and promising genetic lines were included to give comparative information as to their potential value as future varieties.

CICA 4 produced higher yields than any of the other commercial varieties over the two-year period. IR22 produced approximately 77 percent of the IR8 yield. Both of these two varieties produced 2 to 2.5 times the yield of Bluebonnet 50 and Starbonnet.

With respect to the genetic lines, the highest yields were produced by the IR841-63-5-1B selections. In some cases, the yields were 700-800 kg/ha higher than yields of CICA 4. Line IR665-23-3-1-1B, over the two-year period, produced slightly higher yields than IR8. In the 1971 tests, all varieties had to be treated with zinc to produce normal growth. Despite repeated zinc applications, Bluebonnet 50 and Starbonnet showed deficiency symptoms throughout their growth period.

## INVESTIGATIONS WITH ZINC

Zinc deficiency occurred in all of the 1971 fertility and variety trials. The effects were severe enough in some cases to result in the death of 20/30-day-old rice plants.

Sources, methods, and rates of application of zinc were studied in a number of experiments. Some evaluations were also made on the tolerance of varieties to low availability of zinc in soils. Soil samples were sent to IRRI for analyses and a set of leaf samples was sent to the Tennessee Valley Authority Laboratory. The analytical data from these samples are shown in Tables 2 and 3.

TABLE 2. **Soil analysis values.**

| Depth of soil | pH | Available Zn ppm* |
|---|---|---|
| 0 - 10 cm | 8.1 | 1.4 |
| 10 - 20 cm | 8.1 | 1.0 |
| 0 - 20 cm | 8.1 | 1.4 |

* Extracted with EDTA $(NH4)_2CO_3$ solution.

TABLE 3. **Nutrient content of CICA 4 rice leaves.***

| Leaf condition | Zn ppm | Fe ppm | Mn ppm | P Percentage |
|---|---|---|---|---|
| Slight Zn deficiency | 14 | 78 | 406 | 0.127 |
| Healthy leaves from Zn deficiency plants | 22 | 79 | 198 | 0.266 |
| Severe Zn deficiency | 17 | 127 | 277 | 0.236 |
| Healthy leaves from normal plants | 38 | 71 | 516 | 0.165 |

* Dry ashed for 6 hours at 475°C.
Courtesy TVA.

The chemical analyses show that the soil was low in available zinc at all depths and that the subsoil sample was still more deficient than the surface samples. Zinc deficiency symptoms were more severe where the surface soil had been removed in leveling operations or in levee construction.

The values for zinc content in Table 3 appear to be correlated with published values related to the appearance of the rice plants. Completely normal plants had a zinc content of 38 ppm as compared to 14 and 17 ppm for the plants showing zinc deficiency symptoms.

One experiment compared sulphate of ammonia and urea (200 kg N/ha) at different levels of zinc oxide. The results are shown in Table 4.

The data indicate that there was no real difference in the two nitrogen sources and that the yields were highest in the highest zinc treatment. The increases per unit of zinc added were less, however, in the higher rates as compared to the lower rates.

Three sources of zinc, zinc oxide, zinc sulphate and zinc polyflavonoid were used at 8, 16 and 32 kg/ha of actual zinc in two separate experiments. In one experiment, the zinc was incorporated in the soil before transplanting; in the other, the zinc was applied in standing water at the time of the zinc deficiency symptoms. The results of the two experiments are combined in Table 5 and Fig. 1.

All three materials are good sources of zinc, and there was little difference among them. When incorporated in the soils, the major part of the yield increases was produced with 8 kg/ha of zinc, although the highest yield was produced with the 32 kg/ha application.

When applied in the water at the appearance of the zinc deficiency symptoms some 15 to 20 days after transplanting, there was an almost linear response. The yield increases were about 50 percent of those obtained in the experiment in which the zinc was incorporated in the soil before transplanting. These differences are due, in

TABLE 4. **The effect of different sources of nitrogen on the zinc requirement for CICA 4.**

| Zinc applied | Sulphate of Ammonia* | Urea* | Average |
|---|---|---|---|
| 0 | 5,267 | 5,907 | 5,587 |
| 15 | 6,593 | 6,397 | 6,495 |
| 30 | 7,481 | 7,161 | 7,321 |
| 45 | 7,984 | 8,260 | 8,122 |
| 60 | 8,638 | 8,790 | 8,724 |
| 120 | 9,128 | 9,734 | 9,431 |
| Ave. | 7,515 | 7 541 | |

* 200 Kg N/ha.

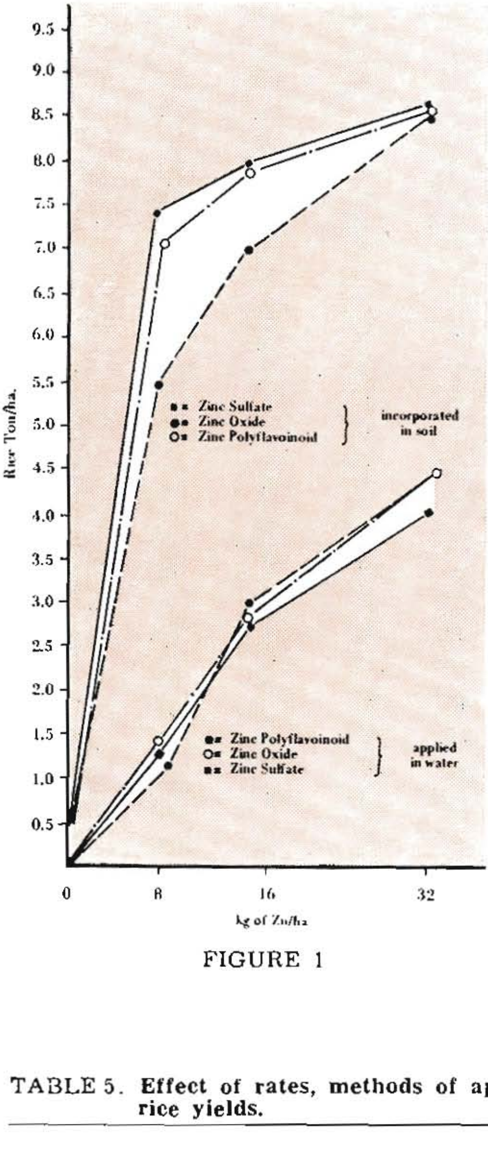



FIGURE 1

part, to the difference in time of application as well as the method of application.

In another experiment, the roots were immersed in zinc suphate solutions of 1, 2 and 4 percent concentrations and for various periods of 1, 2 and 4 minutes before transplanting. Although the treatments gave good growth response during the initial six to seven weeks of growth, even the highest treatments were inadequate, and little to no grain was produced.

Foliar applications using 0.25 percent Zineb, 0.5 percent zinc sulphate and 1 percent zinc polyflavonoid were also tested. The better sources appeared to be zinc sulphate and zinc polyflavonoid, but a minimum of five applications was required.

The material Agrimins (Zn content 0.8 - 1.0 percent) was also checked as a zinc source. The data indicate that up to 150 kg/ha of the material corrected the deficiency in these soils.

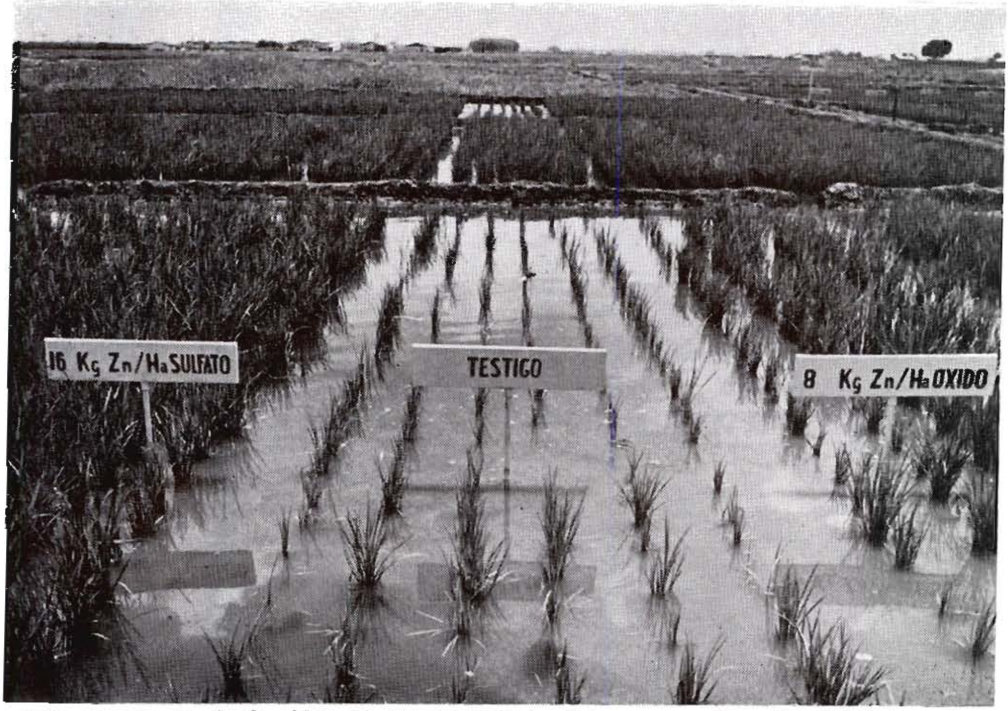
In general, high nitrogen rates aggravated the condition and, in some cases, yields were nil where no zinc was applied. Zinc alone increased yields but both nitrogen and zinc were required for high yields.

An evaluation of the tolerance of varieties to low availability of Zn in the soil was also made. The ratings are shown on Table 6.

Colombia 1 and ICA 10 were selected on the Instituto Colombiano Agropecua-

TABLE 5. **Effect of rates, methods of application and sources of zinc on CICA 4 rice yields.**

| Source of zinc | Rate of Application Kg Zn/ha | Grain Yields: Incorporated in soil before transplanting Kg/ha | Grain Yields: Applied in water Kg/ha |
|---|---|---|---|
| Check | 0 | 368 | 0 |
| Zinc oxide | 8 | 5,484 | 1,243 |
| Zinc oxide | 16 | 6,934 | 2,810 |
| Zinc oxide | 32 | 8,456 | 4,337 |
| Zinc sulphate | 8 | 7,310 | 1,345 |
| Zinc sulphate | 16 | 7,964 | 3,527 |
| Zinc sulphate | 32 | 8,595 | 3,935 |
| Zinc polyflavonoid | 8 | 7,043 | 1,419 |
| Zinc polyflavonoid | 16 | 7,858 | 2,690 |
| Zinc polyflavonoid | 32 | 8,502 | 4,474 |




**Rice growth on both sides of the untreated plot was greatly stimulated by zinc applications to the soil.**

rio farm at Palmira on soils similar to those on the CIAT farm. Their tolerance to low soil zinc was probably an unrecognized factor in their being selected.

## PATHOLOGY

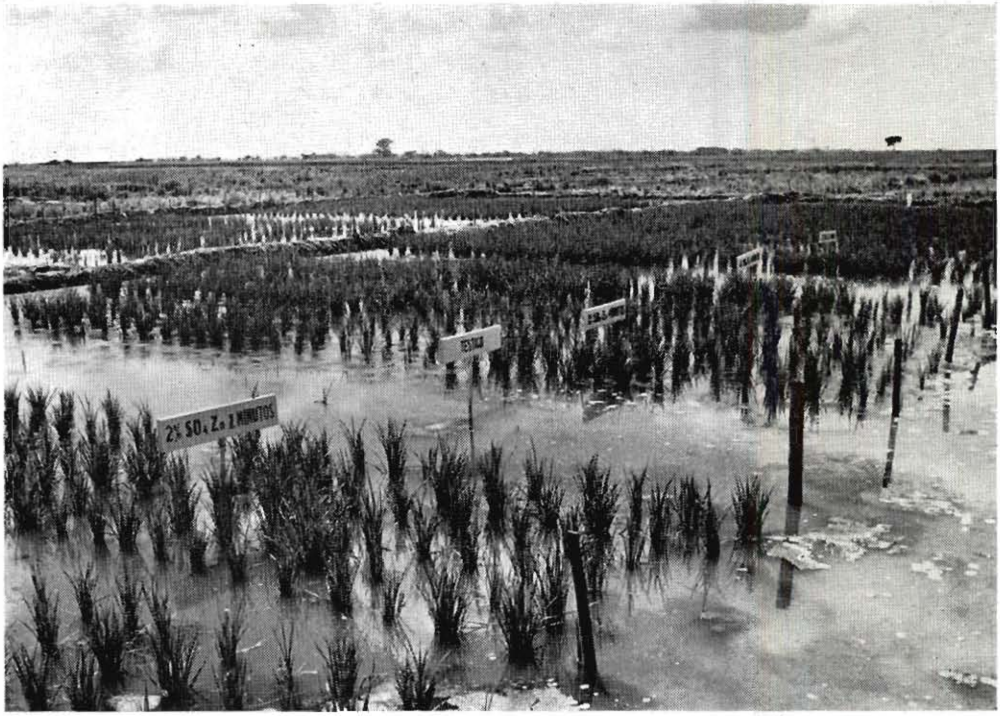
Of the rice diseases present in the Americas, blast is still considered one of the most limiting factors in rice production. Most research efforts were concentrated on finding a suitable control for this disease.

### BLAST

The causal agent of blast, the fungus **Pyricularia oryzae**, is quite variable. It

TABLE 6. **Tolerance of varieties to low availability of zinc in soils.**

| Variety | Rating at 30 days | Rating at 60 days |
|---|---|---|
| Colombia 1 | Highly tolerant | Highly tolerant |
| ICA 10 | Highly tolerant | Highly tolerant |
| Starbonnet | Susceptible | Susceptible |
| Bluebelle | Plants died | — |
| Bluebonnet 50 | Very susceptible | Highly susceptible |
| IR665-23-3-1-1B | Susceptible | Susceptible |
| IR8 | Susceptible | Very susceptible |
| IR22 | Susceptible | Very susceptible |
| CICA 4 | Susceptible | Very susceptible |



**The untreated plots in this zinc experiment were so severely affected by the deficiency that the rice plants died 2 to 3 weeks after transplanting.**

usually develops new races before the breeder can develop varieties having vertical resistance. Two major lines in its control were undertaken, one to help the breeding program find varieties with "partial resistance", which would be generally resistant to the present and future races of the pathogen, and the other to find an efficient way to control the disease chemically.

#### Partial Resistance

In April, 1969, 1,990 varieties, selected for resistance (type 1-4 lesions) in several countries, were tested in the Llanos Orientales, Colombia, where the the disease is endemic and epiphytotic. After 23 trials in that locality and three in Monteria, Colombia, and one in La Selva, Peru, only 210 have remained resistant. Some of these varieties —Tetep, C46-15, Mamoriaka, Carreon, Colombia 1, Colombia 2, Colombia 3, Milagrosa, R-67, Dissi Hatif, Perola, and Iaca Escuro— showed a broad spectrum of resistance to the races of **P. oryzae.**

#### Nature of partial resistance to Pyricularia oryzae

Greenhouse and laboratory studies with susceptible, intermediate and resistant varieties and with the most virulent races isolated from Brazil, Colombia, and Peru, indicated that the type of the lesion, its size, color, and the number of conidia produced per lesion are important factors in determining partial resistance to **P. oryzae.** Susceptible varieties showed larger size (type 4) and a greater number of lesions. Sporulation took place in less time and the number of spores produced was considerably higher. Intermediate varieties in certain cases had type 3 lesions but they produced more conidia. This implies that lesion size is not the only factor controlling resistance. Large size lesions producing few conidia may be more important epiphytologically than smaller size lesions, but may also be active conidia producers. In general, type 3 lesions produced fewer conidia than type 4.

Sporulation was higher in the greenhouse than in the laboratory. The leaves became yellow and died in five days; this might be the reason for the smaller number of conidia observed in the laboratory studies. The time from inoculation to sporulation initiation was shorter in susceptible varieties than in intermediate ones. However, the time difference was small. Type 3 lesions produced more conidia than type 2 lesions, in general, but in some cases a high sporulation occurred in type 2 lesions.

Daily discharge of conidia was different for the susceptible and intermediate varieties. High sporulation occurred during the first days for type 4 lesions of Fanny and Bluebonnet 50. The type 4 lesions of Iaca Escuro always produced few conidia, an important epiphytological factor in the development of the disease. Colombia 3 had type 3 lesions but they produced more conidia after the fifth day. This kind of late discharge resistance may be a critical factor in an efficient chemical control combined with partial resistance of rice to **P. oryzae.**

**Correlation between leaf and neck rot infection**

In general, panicles are found to be more susceptible than leaves. The screening method is based upon the leaf infection of seedlings 30-35 days after planting under natural conditions in epiphytotic areas. The screening of lines for resistance depends upon a good correlation between leaf and panicle susceptibility to **P. oryzae.**

Plants of susceptible, intermediate, and resistant varieties were inoculated with four races of the fungus at 15, 30, 45 days and booting stage, using a concentration of at least 40 conidia per 100 x microscope field. The results indicate that the varieties highly susceptible and resistant gave uniform reactions at the various stages of growth. Some varieties such as Nahng Mon S-4 and IR8, which are susceptible in various locations to several races under field conditions, were resistant at the seedling stage to all the races but susceptible to neck rot to some races.

This suggests that some isolates are non-pathogenic to leaves but are able to infect the panicles. These two varieties have been consistently resistant to the four races used at the seedling stage. Experiments with a large number of varieties are planted in the field to study more critically this important correlation.

**Races of** P. oryzae **in Latin America**

Through cooperative work with the Instituto Biologico, Sao Paulo, and the Instituto Rio Grande do Arroz, Porto Alegre, in Brazil, the Estacion Experimental "La Molina", Lima, and the Universidad Pedro Riuz Gallo, Lambayaque, Peru, races of **P. oryzae** were determined by using the international set of differential varieties. Seventeen races were determined in Brazil, 14 in Colombia, and 25 in Peru.

Some races such as 1A-1, 1A-65, 1C-1, 1D-6, 1D-13, 1G-1, 1G-2, 1H-1, and II-1 are more prevalent and virulent. The same races are present in Southeast Asia, Japan, and the United States. This information might help in screening lines or varieties for partial resistance under artifical greenhouse or laboratory conditions.

**Variability of** P. oryzae

The fungus consists of many races. In addition, constant variability in pathogenicity has been reported. However, races IB-1, IC-1, IG-1 and ID-8 have kept their specific pathogenicity for four years after frequent subculturing. Races IC-1 and IG-1 are often found throughout the world and this may explain why they do not change their racial pattern as reported for other races.

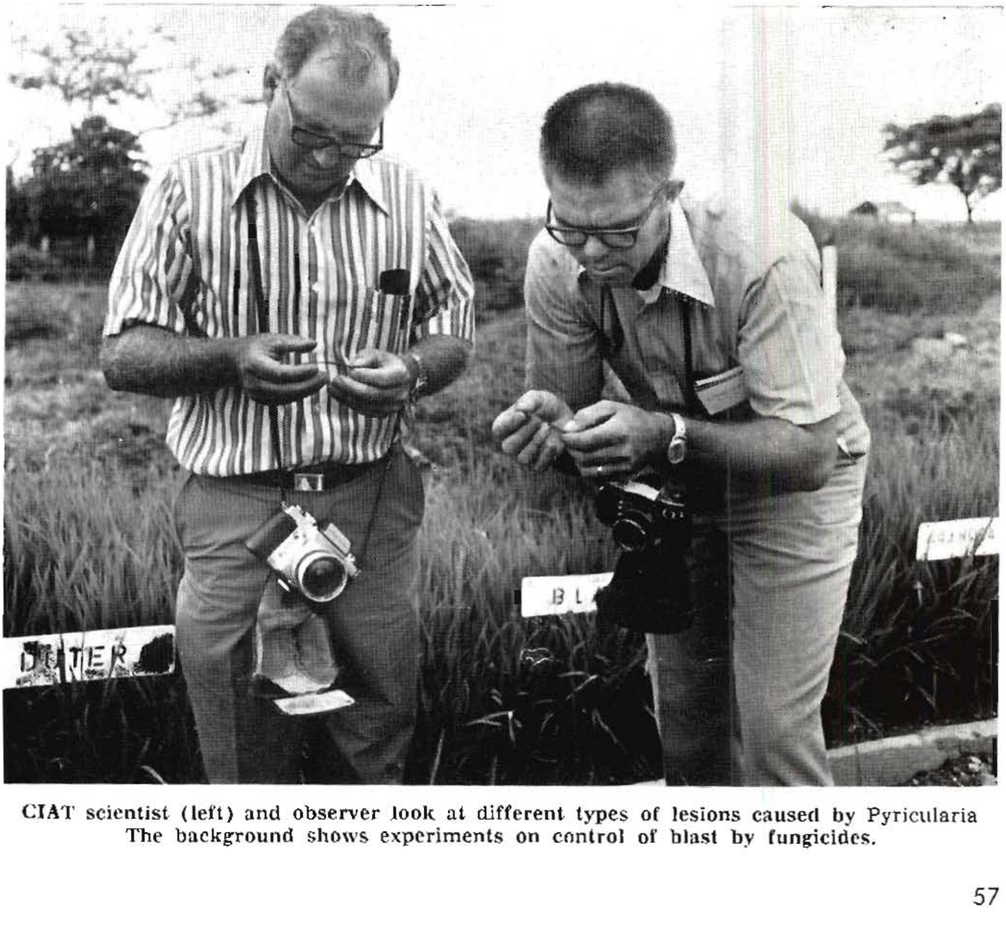
### Chemical control of blast

Resistance is the most effective and least expensive way to control blast; chemical control, however, can reduce losses and may be useful in an integrated control with partially resistant varieties.

There are two climatic areas to be considered for chemical control. First, regions where there are favorable conditions for the development of the disease, with inconstant rainfall, and second, locations where it rains almost continuously. In the first region, it is possible to control the disease economically with fungicides. In locations having the continuous and heavy rains, it will be necessary to develop special means of application to overcome the immediate washing-off of the applied chemicals.

### Seed treatment

Seeds of the highly susceptible variety Fanny were treated with 35 different chemicals. The fungicides Benlate (1 kg a.i./100 kg seed), Demosan (26 kg a.i./100 kg seed), Decafetin (8 kg c.p./100 kg seed) and NF-44 (2.8 kg a.i./100 kg seed) protected the plants for 60 days. The percentage of dead-leaf area was 8, 5, 3 and 4 percent respectively, as compared with 85 percent of the check plot. The readings were taken 30 and 60 days after planting.



CIAT scientist (left) and observer look at different types of lesions caused by Pyricularia The background shows experiments on control of blast by fungicides.

### Aerial applications

Applications at the booting stage, and two more at weekly intervals thereafter, increased yields of the variety Bluebonnet 50 up to two ton/ha as compared with the check in locations of high neck rot infection and intermittent rains.

The fungicides Benlate (0.25 kg a.i./ha), NF-44 (0.21 kg a.i./ha), Hinosan (0.35 l.a.i./ha), Kitazin (0.63 l.a.i./ha), Kasumin (0.03 l.z.i./ha), and Bla-S (0.06 l.a.i./ha) consistently controlled the disease effectively and economically. Mixtures of Benlate (0.100 kg a.i./ha) and Kasumin (0.02 kg a.i./ha) increased the effectiveness and reduced the cost of control. The same treatments under heavy and continuous rains did not give any control. Greenhouse experiments showed that Benlate has a residual effect of up to 12 days, giving a good control even a week after foliar applications.

### Soil treatments

The development of systemic fungicides offers the possibility of controlling the blast disease by soil applications.

Thirty-five fungicides were screened using a rate of 100 kg a.i./ha, with the variety Fanny as the test plant. Of these, Benlate, NF-44 and NF-35 were the most effective. In different experiments NF-44 controlled blast better than Benlate at lower rates, but they were still too high to be economical. Preliminary experiments, in which Tween 20 at 1 percent was mixed with the systemic fungicides, showed improvement in control at lower doses.

Monthly plantings in plots previously treated with these systemic fungicides were effective in the soil for more than 150 days. They suggest that it is possible to control blast by using low cost soil applications with an improved application method.

Granular Kitazin did not control blast when applied directly to the soil with upland rice; it was affective when applied to irrigated rice. This granular fungicide might be economically useful in applications to irrigated rice one week before heading, because it became effective three to four days after application, reached maximum effectiveness after five to seven days, and then gradually became less effective.

## HOJA BLANCA

The importance of hoja blanca has diminished in recent years, presumably because of improved varieties resistant to the vector **Sogatodes oryzicola.** The active and the non-active colonies were maintained for future studies.

Preliminary experiments to trace the virus in the vector did not show its presence in the genitals of either the female or the male. Direct identification of the virus particles was possible in rice, barley, wheat and also in barnyard grass (**Echinochloa colonum**). The long, flexous, thin threads were found in the cytoplasm as well as in the nucleus. These particles broke down readily in purified and leaf-dip preparations, making it difficult to determine their length.

## HELMINTHOSPORIASIS

A disease that attacks the panicle and causes a brown coloration of the grains similar to that caused by **P. oryzae** was observed on selections of IR822. A fungus, **Helminthosporium** sp., was consistently isolated. Pathogenicity tests showed that it was the causal agent. This disease is also present in Brazil, and it may become important in the future.

## SHEATH BLIGHT

This disease is causing serious losses in several regions of Colombia. It has become one of the most common and destructive diseases. Several isolates of the fungus **Corticium sasakii** have been obtained from many locations and from different varieties, particularly Tapuripa. Studies on the growth of the fungus,

**Experiment on partial resistance to rice blast disease. Attendants at the CIAT symposium on the Horizontal Resistance to Rice Blast disease.**

ecology of the disease, susceptibility of the rice plant at several stages, and development of a suitable mass screening method for resistance will be carried out.

RICE BLAST SEMINAR

The importance of this disease as one of the limiting factors in rice production in the tropics prompted CIAT to organize a conference to review the present status of knowledge about partial (horizontal) resistance of rice to **P. oryzae.** Seventeen scientists working with **P. oryzae** and in related fields were invited to participate. They presented 15 papers. Approximately 100 observers were also present from 17 countries in America, Asia and Africa.

The scientists agreed that there are varieties having a broad spectrum of resistance, but not horizontal resistance as it is defined. Variability of the fungus,

**Reaction of rice seedlings to mechanical damage caused by Sogata. From left to right: susceptible, segregating, and resistant.**

phenotypically stable versus unstable races, changes in pathogenicity, the perfect stage of **P. oryzae,** correlation between seedling and neck rot infection, and the status of rice blast in various countries were subjects discussed during the three-day seminar.

## ENTOMOLOGY

**Sogatodes** is the most important insect pest in Latin America because it directly damages the leaves and transmits the hoja blanca virus. The development of commercial varieties with resistance to the insect has checked the spread of the disease. Because of the possible appearance in the future of a biotype adapted to the resistant varieties in some ecological areas in Latin Amercia, plans have been made to survey rice areas to identify quickly new biotypes.

Stem borers (**Diatrea** sp. and **Rupella** sp.) in certain areas of Latin America produce serious damage. For that reason, experiments are being conducted to screen breeding material for resistance. Plant suckers of the **Pentatomidae** and **Corimelaenidae** damage the panicle. A technique is being developed for screening resistant varieties under screenhouse conditions.

**Hydrellia** sp., a leaf miner, is common in the Cauca Valley, although it is easily controlled with the application of Diazinon. Work is in progress to study and correctly identify the species involved.

## WEED CONTROL

One of the most serious rice production problems on the CIAT farm is the preparation of land for seeding. In fields

Applying herbicides with lightweight boom sprayer to kill harvested rice plants and reduce contamination in experimental areas.

that are difficult to drain, weed plants continue growing at vigorous rates. First efforts were to test the possibility of chemically preparing land.

The two dominant species were **Brachiaria mutica** (para grass) and **Heteranthera reniformis** (mudplantian). Three areas were studied, two with nearly pure stands of the individual species, and the third with a balanced mixture of the two, with the following general results:

1. Unless the standing water is removed, these weeds are not properly controlled by such usually effective herbicides as 2, 4D, 2, 4, 5-T, Dicamba and MCPA.
2. **Heteranthera** is controlled equally well by both 1.5 kg active ingredient/ha 2, 4-D and 2, 4, 5-T.
3. Because of the resistant nature of these species and the dense foliage of **Brachiaria,** split applications should be made with 7 to 10 days between each one.
4. Adding a small amount of paraquat to 2, 4-D or 2, 4, 5-T did not increase control, as has been indicated in another species.

A follow-up experiment will use the more effective treatments in these trials in split application and then use pre-germinated rice seed.

Another study is comparing herbicide selectivity using either dry or pre-germinated rice seed. We expect a loss of selectivity with several pre-emergance and late pre-emergence herbicides when pre-germinated seed is used, as the chemical comes into direct contact with the seed.

We are comparing the competitive ability of rice in both seeding methods in the same trial. In theory, pre-germinated seed gives the rice a much quicker start and thus reduces weed competition.

Future work in chemical control will focus on upland rice. The problems are much greater because products must give longer control than is presently obtained when there is no water to give good cultural control. Upland weed species often tend to be more resistant than those in flooded rice fields.

## SOILS

### Lowland rice production on acid oxisols in the Llanos Orientales

The eastern plains of Colombia (Llanos Orientales) are characterized by very acid and highly leached soils, and a native savannah vegetation. The soils are classified as oxisols with gradients to ultisols in the lower-lying areas. Flooded rice is the most important commercial crop. The production is limited to about 20,000 has, all of which are located on the western edge of the llanos, at the foot of the Andes. Rice yields are generally low, 3-4 ton/ha, because of low soil fertility, high blast incidence, and a physiological disease called "anaranjamiento" or orange leaf disease CIAT scientists initiated research in 1969 to determine the cause of "anaranjamiento" as well as soil management practices to overcome the problem. The pot and laboratory study was done at ICA's Palmira research center using soil from Carimagua.

#### I. "ANARANJAMIENTO"

Flooded rice grown in the llanos normally appears rather healthy and green during the first month of growth. During the second month, however, the plants become stunted, have insufficient tillering, and the leaves start turning yellow to orange. Typical "anaranjamiento" begins with yellowing at the tip of the lower leaves, progressing down the leaf, especially along the margins, and moving up the plant to the higher leaves. The lower leaves eventually dry up and die. The slowly formed new green leaves may give the appearance of a later recovery, but the plants remain stunted and the yellowed leaves never turn green. The Fe content in the leaves is seldom above levels usually considered toxic (300 ppm). The roots of affected plants are generally short with few rootlets and are covered with a red iron oxide deposit. Sometimes the root tips are slightly enlarged and dark red. Most roots seem inactive.

Because "anaranjamiento" is only observed in flooded rice grown on llanos soils, it was postulated that it was due to a nutrient deficiency or a reduction-product toxicity. The latter seemed to be more likely since high applications of N, P, K and trace elements did not alleviate the problem. Since the soils are high in Fe, and the symptoms are similar to the yellow type of Fe toxicity symptoms, the disease was thought to be due to Fe toxicity. The chemical kinetics of the soil after flooding were studied, with special attention being given to changes in the Fe concentration in the soil solution.

## A. The chemical kinetics of the soil and the growth of rice

Two sets of experiments were conducted to determine the effect of various treatments on the chemical kinetics of the soil. The experiments were done with 6 kg soil in plastic pots in the screenhouse. Every week, soil solutions were extracted from a glass-T in the bottom of the pots, and simultaneously analyzed for pH, Eh and conductivity in a specially built cell containing one glass electrode, one calomel electrode, two Pt electrodes, and a conductivity cell. Extraction and analyses were conducted under $N_2$ gas to prevent oxidation of the solution by contact with air. The solutions were then acidified to prevent oxidation, and analyzed for Fe and Mn.

During the first semester the soil was mixed before planting with 50 kg/ha N (urea), 150 kg/ha $P_2O_5$ ($Ca(H_2PO_4)_2 \cdot H_2O$), 100 kg/ha $K_2O$ (KCl), 375 kg/ha $CaCO_3$, and 125 kg/ha $MgCO_3$. Top dressings of 75 kg/ha N were made at 30, 60, and 75 days. The treatments included various lengths of time of preflooding before planting, delayed flooding (soil at field capacity for 8 weeks), and $MnO_2$ applications at the rate of 1,000 kg Mn/ha. In preflooding treatments the soil was submerged at 7, 5, 3 and 0 weeks before transplanting. At this time all pots were fertilized and 7-day-old seedling of IR8 were transplanted.

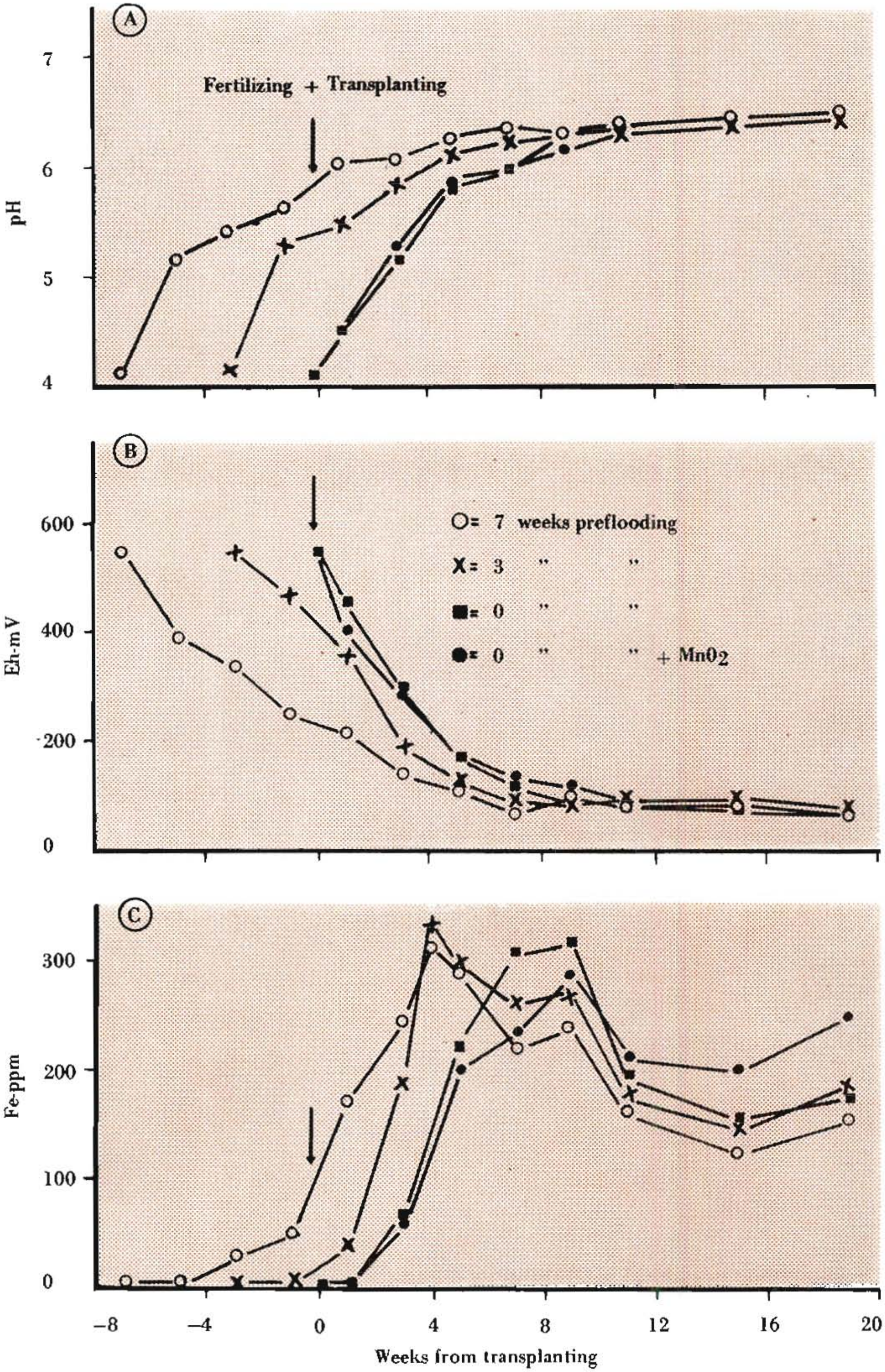
Fig. 2A shows the change in pH after flooding. The pH increased from 4.15 to an equilibrium value of 6.5, but the increase was extremely slow because of a slow reduction. The rate of reduction was much faster in the presence than in the absence of fertilizers. This is indicated by the fact that in the unfertilized soil (seven weeks preflooding) the pH during the initial five weeks increased to only 5.53, while in the fertilized soil (0 weeks preflooding) it increased to 5.84. These soils appear to be so low in fertility that the application of fertilizers greatly increases the rate of reduction. Similarly, with 0 weeks preflooding the Eh (Fig. 2B) decreased more rapidly than with 7 weeks preflooding.

In all cases the Eh decreased from 545 mV to a constant value of about 90 mV in 10-15 weeks. Apparently, the high concentration of Fe buffered the solution at a relatively high Eh. Potentials low enough for sulfate reduction were not observed in the soil solution.

The Fe concentration in solution (Fig. 2C) remained very low for several weeks before rising sharply to a maximum of 300-350 ppm. After the peak, the concentration dropped to a constant level of 150-200 ppm because of precipitation of ferrous hydroxide at the high pH. Fe levels above 300 ppm have been reported to cause direct Fe toxicity in the rice plant. The application of $MnO_2$ had hardly any effect on the pH and Eh, and had only a slight effect on the Fe concentration, reducing the maximum slightly to 285 ppm.

The conductivity of the soil solution increased to a maximum of about 800 micro mhos/cm before decreasing to a constant level of about 600 micro mhos/cm. The Mn concentration also increased upon flooding, but never reached higher than 2 ppm. This precludes Mn toxicity.

After the first semester the soil was dried, sieved, and reflooded for the sec-




FIGS. 2A, 2B, 2C.— Change of pH, Eh, and Fe concentration in Carimagua soil solution after flooding.

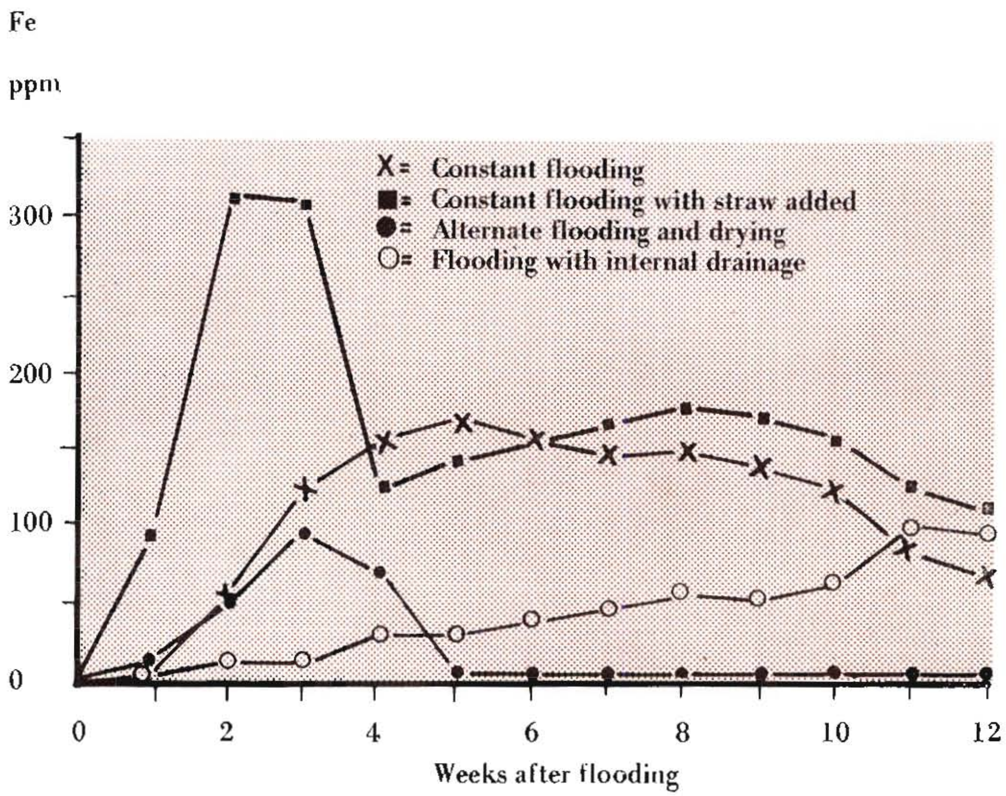



FIGURE 3.— Change of Fe concentration in Carimagua soil solution after flooding

ond semester experiment. Soil analysis showed a markedly higher pH and fertility of this "used" soil compared with a "fresh" llanos soil (Table 7).

Before flooding, the soils were fertilized with the same materials as reported for the first semester, except that the initial N, P, and lime levels were doubled.

The second semester experiment included various water management and other treatments such as wet fallow, constant and rotational irrigation, various drainage systems, and the addition of straw and high levels of lime with the regular fertilizers.

The pH and Eh curves obtained were similar to those in Figs. 2A, 2B. Because this soil had been cropped once before, the initial pH was higher (5.3) and initial Eh was lower (420 mV). The higher fertility level (and probably bacterial population) resulted in a more rapid reduction. Maximum pH levels of 6.5 and minimum Eh levels of 80 mV were reached in only four weeks. The straw and high lime applications slightly increased the rate of reduction and resulted in higher pH and lower Eh values. The rotational irrigation, consisting of 3 1/2 days flooded alternated with 3 1/2 days dry, markedly reduced the pH to about 5.3 and increased the Eh to 300-350 mV.

The differences among treatments were most marked with respect to Fe concentration (Fig. 3). Maximum Fe levels were about 175 ppm in this

TABLE 7

| | ph | P(BRAY I) ppm | P(BRAY II) ppm | Al | Ca | C.E.C. |
|---|---|---|---|---|---|---|
| | | | | | me 100 gm | |
| "Used" soil | 5.29 | 1.47 | 3.19 | 1.8 | 1.16 | 12.4 |
| "Fresh" soil | 3.95 | 1.07 | 2.22 | 3.5 | 0.68 | 13.0 |

"used" soil with continuous flooding. With the addition of 0.4 percent straw, the soil reduced very rapidly, while maximum Fe levels were as high as 310 ppm. Rotational irrigation, started at three weeks after seeding, reduced the Fe concentration to nearly zero, while irrigation with internal drainage (4 cm/day) maintained intermediate Fe levels.

**Plant response.** During both semesters the plant response to treatments was small. The plants were always severely stunted and "anaranjamiento" symptoms appeared around six weeks, being more severe during the first than the second semester. Preflooding did not show any beneficial effect and yields slightly decreased with increasing time of preflooding. The delayed flooding treatment showed "anaranjamiento" only after flooding, resulting in high straw but low grain yields. The $MnO_2$ treatment resulted in more severe "anaranjamiento" symptoms, which may have been due to Mn toxicity (5,500 ppm Mn in leaves), but the final plant growth and yields were better than for any other treatment.

During the second semester "anaranjamiento" symptoms developed irrespective of treatments. Applying fertilizers at time of seeding resulted in higher yields than at time of preflooding. The favorable chemical conditions in the soil due to rotational irrigation or internal drainage were not reflected in higher yields, probably because of fertilizer losses by leaching and denitrification. Midseason drainage at two months resulted in the highest yield of grain. The addition of straw or high levels of lime had no beneficial effect.

From these pot experiments and field observations the following conclusions were drawn:

1. "Anaranjamiento" is not a direct Fe toxicity since it may occur at relatively low Fe concentrations in soil solution, resulting in relatively low Fe levels in the plant. However, it seems to be caused by damage of the root system by a reduction product, most likely Fe. The deposition of Fe oxide on the outside of the root not only limits root growth but also prevents the uptake of nutrients, especially P. In a soil already low in plant nutrients this limited uptake ability of the plant leads to an imbalance between supply and demand. In a large plant with a large demand, a small increase in Fe concentration in the soil solution and subsequent coating of the roots leads to a shortage of nutrients. The plant compensates for that by translocation of nutrients from the lower to the higher leaves resulting in oranging and early senescense of the lower leaves.
   For that reason, healthy plants, grown under conditions of high P and N or low Fe, are always first and most severely attacked by "anaranjamiento", once the Fe concentration in solution starts to build up. Similar conditions of restricted root growth in plants grown in too small a pot, plants grown on compacted soil, or plants from which the roots have been cut, will lead to the same "anaranjamiento" symptoms in other than the llanos soils. Since "anaranjamiento" is a root problem, and primarily a result of extreme P deficiency, foliar applications of P eliminate the symptoms.

2. In soils with a rapid build-up of soluble Fe, the plant remains stunted from the beginning and there is no need to balance the top growth with the limited nutrient supply. In this case no typical "anaranjamiento" develops, but the plants may suffer from direct Fe toxicity, i.e., an excessive uptake of Fe, resulting in brown spots on the leaves. The differences in shade of oranging observed in the field are probably due to various combinations of "anaranjamiento" and direct Fe toxicity, depending upon the age and size of the plant at the time of Fe build-up.

Transplanting rice seedlings of IR 665 - 23 - 1.

Threshing rice from variety experiments to determine yields.

3. A slow reduction results in good initial plant growth, but the subsequent late occurrence of the Fe peak results in severe "anaranjamiento" and a considerable reduction in grain yield.

4. The severity of "anaranjamiento" can be reduced by a combination of water management and fertilization practices designed to maintain a low level of Fe and a constant supply of soluble nutrients in the soil solution.

5. A build-up of soluble Fe can be prevented by intermittent or rotational irrigation. A low Fe concentration during flowering, obtained by mid-season drainage, is advantageous for grain formation. Constant flooding with internal drainage maintains a low Fe level, but the loss of nutrients in the drainage water makes it counterproductive. Preflooding for three weeks has the advantage of passing the Fe peak before seeding or in the early stages of growth, but has the disadvantage that P applied at seeding is more rapidly fixed. For that reason preflooding for more than three weeks is not beneficial.

6. The P fertilization should be a combination of a slow release P source, like basic slag or rock phosphate, incorporated before seeding, and a more soluble P source like triple superphosphate applied on the surface at time of seeding. An additional biweekly foliar application of a 0.5 percent P solution ($KH_2PO_4$) is probably beneficial, but may not be practical.

7. A slow release N fertilizer, such as sulfur-coated urea, would probably be beneficial by providing a constant supply of N, while reducing blast attacks due to excessive N and denitrification losses during soil drying.

## AGRICULTURAL ENGINEERING

Agricultural engineering and station operations have designed and developed 60 hectares for irrigated rice; about 10 hectares have been planted to rice agronomy experiments, and about 32 hectares for rice seed production by crop production trainees. Land development, land preparation, and irrigation have been under the direct responsibility of agricultural engineering and station operations. Varieties, planting, pest control, and harvesting have been handled by the crop production trainees, a rice agronomist and a breeder.

Crop production and agricultural engineering students and trainees and rice trainees were given practical experience in wet land leveling and field irrigation.

An experimental prototype rotatiller has been used for wet soil puddling. A one-meter diameter puddling rotor was designed and developed in CIAT for very soft soils.

Two Japanese rotatillers with rubber tires were provided with cage wheel extensions to work in flooded fields.

One of the major problem areas in the tropics is lack of machinery and labor systems to plant crops during the rainy season. Because 1971 was an unusually wet year, it provided the opportunity to plant rice under saturated soil conditions. Dry land preparation and seeding of other crops proved impractical.

Major irrigation and drainage projects developed for tropical corn production and other upland crops have required excessively high capital investments. The development of suitable wet land preparation equipment would enable these areas to be placed into rice production with a minimum investment. The use of equipment in the continuous production of rice throughout the year would further reduce the cost in machinery investment and provide uniform employment and income. A preliminary rice production system has been implemented on a 50 hectare area with the intention of planting approximately 1/2 hectare per day. Thus labor, machines and land would be in continuous use with

Land levelling under water with a spike tooth harrow.

Preparing wet land with a prototype rotary tiller.

Testing of a powered cylinder for land preparation under water.

Land preparation under water with a small 8 h.p. tractor.

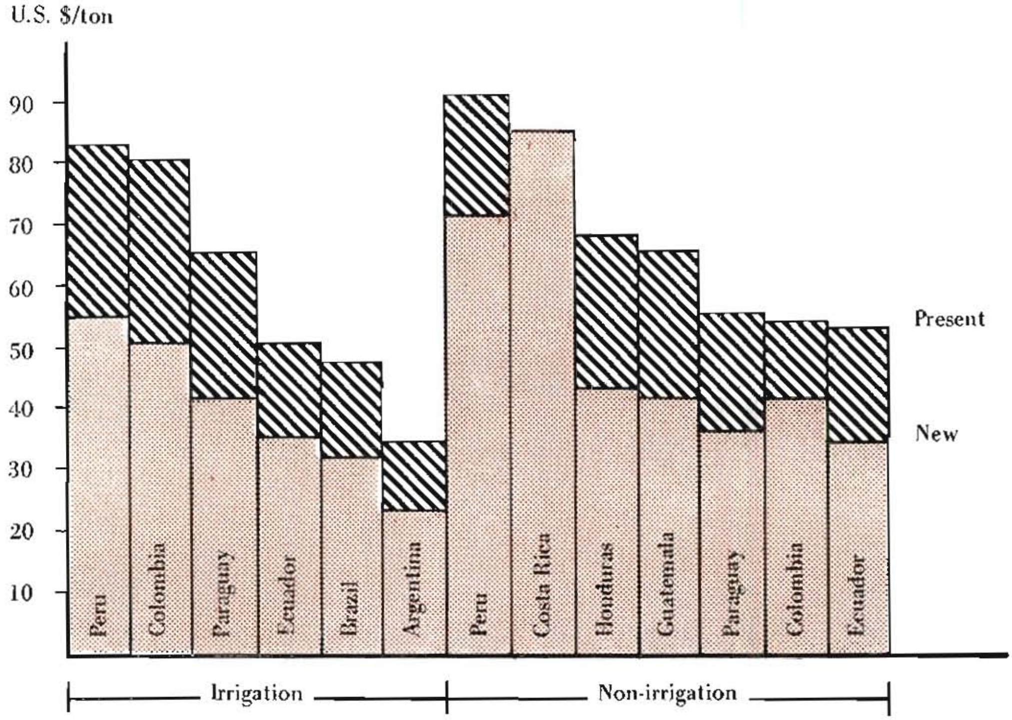



FIGURE 4.— Estimated cost of producing present and new rice varieties in certain Latin American countries (U.S.$ Ton).

an income of 2 to 2 1/2 tons of harvested rice per work day. Many problems must be solved; however, the components necessary will be identified and tried.

## AGRICULTURAL ECONOMICS

### Cost of production

An estimate was made of the cost of producing the traditional and new rice varieties in nine Latin American countries. Basic data were obtained from national agricultural research institutes and/or the Ministries of Agriculture.

The estimated costs of production are reported in Figure 4 and Table 8. The estimates are rough guidelines rather than exact figures. The cost of production tends to vary among regions within any one country and even among farmers within a region. The cost data for each one of the countries are expressed in a common currency (U.S.$) for direct comparisons. The official exchange rates may not correspond to relative domestic purchasing power within the various countries, hence a direct comparison of dollar costs may be biased.

Figure 4 shows that the cost of producing rice under irrigation is low in Argentina while it is relatively high in Peru and Colombia. The cost per ton of rice produced under upland conditions is low in Ecuador, Colombia, and Paraguay while it is high in Peru and Costa Rica. The production cost per ton of the new rice varieties is considerably below the cost of producing present varieties. For example, the production cost per ton of present varieties under irrigation in Peru is estimated to be about $84, while the estimated cost of producing a ton of the new varieties is

TABLE 8. **Estimated cost of producing present and new rice varieties in certain Latin American countries. (U.S.$)** [1]

| Country | Present variety | | | | New variety | | | |
|---|---|---|---|---|---|---|---|---|
| | Irrigation | | Non-irrigation | | Irrigation | | Non-irrigation | |
| | Costs/ha. | Costs/ton | Costs/ha. | Costs/ton | Costs/ha. | Costs/ton | Costs/ha. | Costs/ton |
| Argentina | 170.71 | 34.14 | — | — | 190.13 | 22.37 | — | — |
| Brazil | 166.08 | 47.45 | — | — | 189.48 | 31.84 | — | — |
| Colombia | 403.30 | 80.66 | 86.65 | 54.16 | 433.63 | 51.02 | 112.32 | 41.20 |
| Costa Rica [2] | — | — | 295.34 | 84.38 | — | — | 295.34 | 84.38 |
| Ecuador | 178.00 | 50.86 | 74.57 | 53.27 | 208.96 | 35.12 | 81.42 | 84.21 |
| Guatemala | — | — | 198.55 | 66.18 | — | — | 211.59 | 41.49 |
| Honduras | — | — | 203.50 | 67.83 | — | — | 217.70 | 42.69 |
| Paraguay | 164.08 | 65.63 | 110.48 | 55.24 | 179.14 | 42.15 | 120.74 | 35.51 |
| Peru | 461.36 | 83.57 | 183.55 | 91.77 | 520.14 | 55.43 | 240.05 | 70.60 |

1. From: Vicente W. Anibal S. *Condiciones de Cultivo y Costos de Producción de Arroz en algunos países de América Latina* and Per Pinstrup-Andersen. *Economic Implications of Producing new rice varieties in Latin America*, CIAT 1971.

2. In Costa Rica, "present variety" refers to the new variety IR8.

TABLE 9. **Average internal wholesale prices of rice for certain Latin American countries.**

| Country | 1964 U.S.$/ metric ton | 1964 % of world market price [1] | 1965 U.S.$/ metric ton | 1965 % of world market price [1] | 1966 U.S.$/ metric ton | 1966 % of world market price [1] | 1967 U.S.$/ metric ton | 1967 % of world market price [1] |
|---|---|---|---|---|---|---|---|---|
| Argentina | 80.20 | 58 | 56.50 | 41 | 55.00 | 33 | 51.40 | 26 |
| Brazil | 161.00 | 118 | 116.00 | 84 | 202.00 | 121 | — | — |
| Bolivia | 202.00 | 148 | 206.00 | 149 | 258.00 | 155 | — | — |
| Colombia | 281.70 | 207 | 247.00 | 179 | 256.40 | 154 | 223.10 | 116 |
| Chile | 192.00 | 141 | 225.00 | 164 | 202.00 | 122 | — | — |
| Dominican Rep. | 295.50 | 217 | 323.30 | 235 | 298.70 | 179 | 277.40 | 142 |
| Ecuador | 137.50 | 101 | 157.60 | 114 | 153.70 | 92 | 165.70 | 85 |
| El Salvador | 207.60 | 152 | 211.40 | 153 | 228.90 | 137 | 216.90 | 111 |
| Guatemala | 228.50 | 168 | 239.80 | 174 | — | — | — | — |
| Mexico | 230.50 | 169 | 237.80 | 173 | 256.40 | 154 | 259.92 | 133 |
| Panama | 276.60 | 203 | 273.20 | 198 | 265.30 | 159 | — | — |
| Paraguay | 93.80 | 71 | 87.20 | 63 | — | — | — | — |
| Peru | — | — | — | — | — | — | 147.30[2] | 88 |
| Uruguay | 160.00 | 118 | 158.00 | 114 | 159.00 | 96 | — | — |
| Venezuela | 313.60 | 230 | 281.00 | 204 | 281.10 | 169 | — | — |

1. The price of Thai rice FOB Thailand.
2 Average 1959-63.

about $55. A more detailed discussion of the cost estimates and the underlyng assumptions may be found in the sources indicated in Table 8.

**Price analysis**

On the basis of existing rice prices in the various Latin American countries, an analysis was made to determine the relative competitive position of each country with respect to rice export. Table 9 shows the average internal wholesale price of rice for each one of a number of Latin American countries. To obtain some indication of the relative competitive position of each country, the internal prices were estimated as a percentage of the export price of Thai rice f.o.b. Thailand (Table 9). The price of Thai rice appears to be a good index of general world prices.

Table 9 shows that rice prices tend to be low in Argentina and Paraguay and high in Venezuela, Dominican Republic and Panama. The wholesale prices of rice in countries such as Argentina and Paraguay were below the price of Thai rice during the years included in the analysis. Ecuador shows an improving competitive position. Most other countries show internal wholesale prices above those found in the world market.

A comparison of the internal prices in the various countries with existing world market prices provides a rough guideline for the relative competitive position with respect to export. However, a number of other factors tend to influence the possibilities for export, hence the above price analysis is not sufficient to determine the export possibilities for the countries included in the analysis.

**Utilization of increasing rice quantities**

It is expected that the adoption of the new rice varieties will cause a considerable increase in the quantities of rice produced in Latin America. Given the low price elasticities for rice for direct human consumption, it appears that alternative uses for rice should be identified to avoid drastic price falls and/or large surplus stock accumulations.

Considering these relationships, a study was initiated after the Seminar on Rice Policies to identify such alternative uses and analyze their technical and economic feasibility in Latin America. The specific objectives of the study are: (1) to project the magnitude of the production expansion due to the new varieties in Latin America in the short run, (2) to predict future demand for rice for direct human consumption, (3) to identify and analyze the feasibility of alternative uses for rice, (4) to analyze the potential alternative uses for land presently utilized for rice, and (5) to make recommendations on policy issues related to rice production, marketing and utilization.

## TRAINING

Three trainees from Ecuador were trained in rice and rice seed production and have now returned to Ecuador. One trainee from Brazil is being trained in the same program. A postgraduate intern from Colombia and a research scholar from Ecuador finished their training and M.S. studies in rice pathology.

Five trainees from Brazil, Ecuador, Honduras, and Venezuela spent about six months each in rice breeding or agronomy and seed production.

## INTERNATIONAL COOPERATION

During 1971, visits were made to Ecuador, Peru, Nicaragua, Costa Rica, Jamaica and the Dominican Republic to observe rice-growing conditions and to advise on problems of rice production. Most of these countries now have CICA 4 in their seed multiplication programs.

During 1970, CIAT supplied 3,956 seed lots including segregating lines and bulk populations to cooperators in Latin America. Major nurseries went to Guatemala, Honduras, Costa Rica, Venezuela, Ecuador, Peru, Argentina, and Brazil.

# Maize

## Production Systems

The majority of farmers in Latin America plant maize in small plots near their houses or in fields of five hectares or less. The crop is characterized by low plant population, limited insect and weed control, poor fertilization, and local varieties. Yields average less than 1,000 kg per hectare. There has been relatively little research and extension work directed at this farmer, especially in the lowlands of the Andean zone.

Commercial maize production employs available hybrids, moderate rates of fertilizer, granular insecticides, and chemical weed control. Most research has been directed toward this cultural system, and current yields average three to six tons throughout the zone. The maize program works with these two distinct cultural systems, and complements the efforts of national programs in the search for high-impact schemes to raise production.

### MAIZE BREEDING

The collection and testing of promising germ plasm from a wide range of sources continued. In addition to direct requests from national and commercial programs for seed, we have planted a series of international trials. These include the International Maize Adaptation Nursery (CIMMYT), the commercial, experimental, brachytic and opaque trials from Central America (PCCMCA), two trials from the Inter-Asian Program (IACP, Thailand), and several early generation trials from CIMMYT. In most of these trials, limited crosses among selected lines were made to test new and promising combinations in the next cycle. This rapid selection, development and testing scheme has been used with remarkable success in CIMMYT to reduce plant height of tropical maize. The selection criteria we employ include low plant height, early flowering and harvest dates, efficient dry matter production, and resistance to prevalent pathogens and insect pests. Testing of these materials will take place in regional stations as well as at CIAT.

A series of promising populations was planted in 1971 for observation and selection. These will be carried through breeding cycles following several schemes: mass selection, modified mass selection, reciprocal recurrent selection in two populations, and traditional inbreeding and hybrid formation. This series will be implemented in the field primarily as a training tool, but will always be used with the most promising germ plasm available, so that any end product will be of immediate use. Both traditional hybrid systems and population improvement schemes are included, since national maize improvement programs differ in their approaches, and training should be as broad as possible.

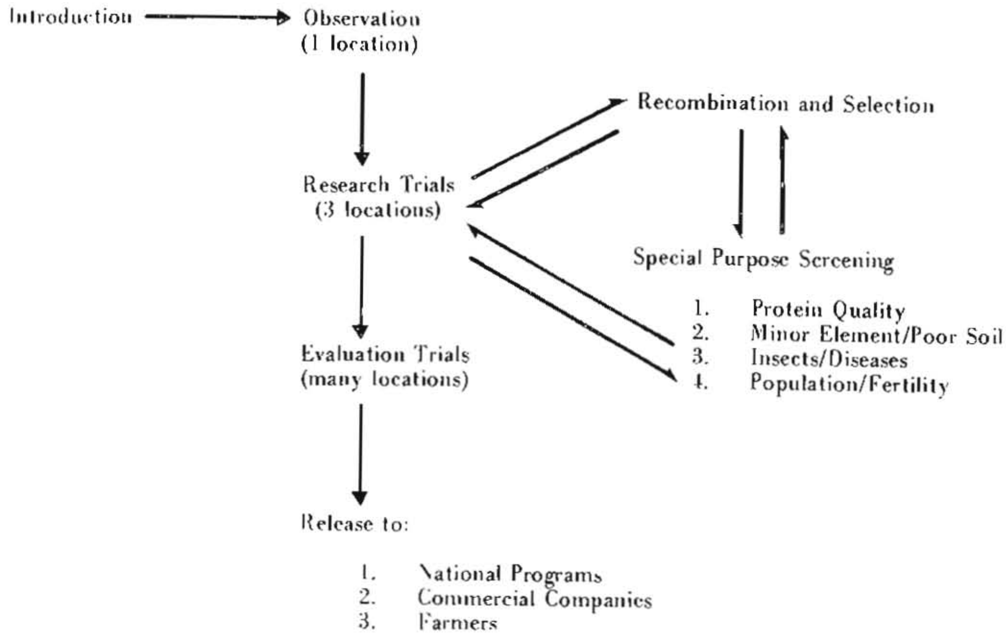



FIGURE 1 — **Flow of germ plasm through evaluation, testing and release in the Maize Production Systems Program.**

**Controlled pollinations in maize allow the concentration of desirable traits into potential commercial varieties.**

**Selection of superior genetic combinations is based on data from replicated yield trials.**

Grain samples are collected in the field to determine moisture and adjust final yields.

Grain samples for moisture determination are carried to the laboratory for evaluation.

A scheme for the flow of maize germ plasm through our program of improvement, evaluation, and release is outlined in Figure 1. This scheme allows an efficient, logical, and yet thorough use of each introduction, and considers the rapid movement of large numbers of materials while minimizing the chance of discarding important germ plasm.

This plan allows rapid evaluation and use of materials. Observations, research trials, and recombinations on an international scale will be a primary responsibility of CIAT. Evaluation trials and special purpose screening are shared by national programs in the zone, commercial companies, and farmers, in collaboration with CIAT. Maize improvement within CIAT includes the participation of crop protection, agronomy and soils, nutrition, economics, and engineering.

## MAIZE PHYSIOLOGY

Wider adaptation of commercial hybrids and varieties is essential in a region where maize is grown in such a range of micro-climates. There is variation in temperature (with altitude), rainfall and relative humidity, available energy, and soil type, especially with respect to minor elements, and considerable variation in day length within Latin America. The area in maize in most micro-climatic zones does not justify an improvement program and specific hybrids for that area. A preferred solution is to select a wide range of broadly adapted varieties or composites which can then be tested in the many zones, and the best material for each zone increased in that specific area. Development of these composites requires testing in collaboration with national programs, as well as more information on factors which influence adaptation.

Photoperiod sensitivity limits north-south exchange of germ plasm. Field studies during 1971 revealed a simple inheritance system for sensitivity—possiby as few as 'two genes—and this genetic pattern is being tested in the current cycle. A study of critical day length was inconclusive, and is being repeated. Development of a broad-based synthetic is underway, and we must determine the optimum system for transfering insensitivity from our source materials into other valuable germ plasm. Materials from other photoperiod projects are being tested in the field in the current cycle: these include CIMMYT, University of Missouri, and Cornell University. Incorporation of insensitivity into promising temperate and tropical materials will facilitate their exchange among breeders.

Temperature sensitivity limits ready movement of materials up and down the mountains in the Andean zone. In collaboration with Colombian colleagues, and with artificial light gradients in the field in two Instituto Colombiano Agropecuario (ICA) stations, Tibaitata (2,600 m) and Turipana (sea level), we are exploring not only the effects of temperature but also i'ts interaction with photoperiod. Preliminary results from Turipana on the north coast indicate that photoperiod sensitivity

**Irrigation in field photoperiod installation. Artificial light extends the natural day and aids in the search for more widely adapted maize.**

disappears, or at least is minimal, under high temperatures (mean temperature 28° C). Another study in collaboration with Purdue University in the same three locations (Tibaitata, Palmira and Turipana) is testing the effects of temperature and light on maize growth, productivity, maturity and protein quality. The three locations with ICA are part of a larger project which includes locations in Mexico and U.S.

An international study of cold tolerance and frost resistance was initiated by Cornell University in 1971. CIAT is coordinating the trials in the Andean zone. In San Jorge (2,900-3,300 m, Colombia), Santa Catalina (3,000 m, Ecuador), and Huancayo (3,300 m, Peru) germ plasm which has survived the rigors of a previous growth chamber test is being screened. These tests will give results on actual resistance to cold and frosts, and also allow a recombination of survivors into a resistant synthetic. Surviving and adapted materials from these three locations in the Andes will be combined with survivors from other locations—Nepal, Kenya, New Zealand, and New York—into an international composite for use by programs throughout the temperate and high altitude tropical world.

Plant type and production efficiency are continuing concerns of the breeder. Selection schemes currently emphasize short stature, early maturity, fewer leaves and smaller leaf area, and multiple ears. Efficient use of light, nutrients and moisture, plus the need for better resistance to lodging, dictate the need for a smaller plant. In the current season we are testing 50 sorghum lines of diverse origin which represent shorts and talls, early and late types, leafy versus sparse foliage, upright and horizontal leaves, open versus closed panicles, a range in grain color, and other unusual characteristics. Yield data will be related to morphological characteristics of the plant to determine whether there are some types more efficient in dry matter production per day. Similar studies are planned for maize.

## MAIZE AGRONOMY

Micro-element deficiencies continue to predominate among our agronomic problems at CIAT. Rates of boron between 2 and 3 kg/ha can apparently correct the observed growth and sterility problems which have depressed maize yields over several seasons. The zinc deficiency, severe in rice, also affected maize in one lot; either foliar application or a soil drench with zinc sulfate reduced foliar symptoms of the deficiency. A sorghum nursery now in the field shows tremendous differences among varieties in response to apparently low boron levels. Deficiency results in white streaks on the leaves, vegetative proliferation, delayed or no development of the panicle, and non-uniform growth.

A screening trial is in the field in the eastern plains at Carimagua, where 20 varieties and hybrids of maize and 50 of sorghum received low and high lime applications, plus different levels of applied phosphorus. Promising results from this cycle suggest that screening crop species may provide a resistant type which can be further selected or used directly under these adverse soil conditions.

## MAIZE PLANT PROTECTION

**Entomology.** Maize and sorghum crops on the farm in the first season of 1971 were seriously attacked by the stalk borer **Diatrea**; average counts of entry holes/stalk were six in maize and three in sorghum. The observation nursery of sorghum showed striking differences in susceptibility to this borer, and a replicated screening test was planted in the second season. More than 300 sorghum collections and 100 maize types were planted in this field, but the level of attack was greatly reduced. This research problem will be minimized with a new artificial rearing effort which will soon provide larvae for artificial, controlled, and uniform infestation in the field. Monthly or twice-monthly plantings of maize, sorghum, and legumes will be initiated to observe seasonal fluctuations in insect populations.

A small trial of promising formulations of commercial granular insecticides showed excellent control of **Spodoptera** sp., but the differences among treatments were not great because of a natural control of the insect by a **Braconidae** that reached a level of 40 percent control in combination with a parasitic fungi that produced **80 percent** control this season. This fungus which attacks **Spodoptera** in the field has been identified with the help of the University of California as **Metarrhizium anisopliae.** These screening and dosage trials are valuable for the development of production systems for the CIAT farm, and particularly for training entomologists in the complete range of activities they will face in a national or commercial program. The availability of a parasitic fungus for control of **Spodoptera** creates new possibilities for the farmer. Emphasis in the CIAT program remains on integrated control and the use of a minimal amount of insecticide that will reduce the cost of production and preserve natural predator populations.

**Pathology.** The maize dwarf mosaic virus has not been reported in Colombia. In October, the visit of a Brazilian electron microscopist and our observations in the field of virus-like symptoms led to identification of this virus on both maize and sorghum at CIAT. Inoculation and transmission studies are in progress. Neighboring maize and sorghum fields in the Cauca valley have only trace infections of this aphid-transmitted virus. Breeding materials will be screened for resistance in the next field cycle. Monthly plantings of maize, sorghum, cassava, and legumes will provide data on seasonal fluctuations in natural inoculum of pathogens in upland crops.

**Weed Control.** Trials were planted in the second season to evaluate separately the effects of competition from broad-leaf and grass species in the maize crop. The timing of competition, effects of fertility and plant population are other factors included in these tests. Each trial will be repeated in several seasons to provide realistic results. Sensitivity to atrazine in some maize and sorghum lines is of immediate commercial concern. Because of the wide use of triazine herbicides by farmers, all improvement programs must either use atrazine as a routine application or test lines for sensitivity before they are taken through many cycles of improvement.

## MAIZE ECONOMICS

A multi-disciplinary analysis of the factors associated with low maize yields in Colombia was initiated in late 1970 (see Annual Report 1970). The objectives of the study are: (1) to identify important factors associated with low maize yields among small farmers in certain selected regions of Colombia, (2) to determine the interrelationships among these factors, (3) to suggest avenues of approach to the problem of increasing yields, and (4) to develop a methodological framework which may be applied in similar studies in other regions.

A model was developed to illustrate the most important relationships believed to exist among the factors determining maize yields. Three sets of factors seem to directly determine yield: (1) natural factors such as soils and weather conditions, (2) quantity and quality of inputs used, and (3) management. Input use and management, in turn, are determined by a number of other factors. The quantitative analysis of this project will be terminated in the beginning of 1972.

## MAIZE PROTEIN QUALITY

**1. Selection of flint-type opaque-2 maize.**

TABLE 1. **Laboratory analyses and biological evaluation of flint and opaque selections from H-208, compared to casein and to normal maize.**

| Lab Analyses | Casein | H-208 opaque | H-208 flint | H-207 normal |
|---|---|---|---|---|
| Protein | | 8.9 | 9.6 | 9.9 |
| Lysine | | 4.0 | 3.7 | 2.7 |
| Tryptophane | | .37 | .73 | |
| Rat Growth Studies | | | | |
| PER (prot. effic. ratio) | 3.68 | 3.21 | 2.81 | 1.43 |
| % of casein | 100 | 87.2 | 76.4 | 39.4 |
| N Balance Studies (children) | | | | |
| Digestibility | 98 | 91 | 87 | 78 |
| Net Protein Utilization | 75 | 69 | 65 | 36 |
| Biological Value | 77 | 76 | 75 | 47 |
| N Retention/Day | 1.81 | 1.52 | 1.50 | .93 |

The search for a high quality maize with a flint endosperm continued through two more cycles in 1971. Laboratory and biological results are promising and preliminary studies of nitrogen balance in children confirmed the laboratory and rat data. A summary is presented in Table 1.

The quality of the yellow flint selections is essentially equal to the original floury opaque-2 phenotype. In a white hybrid, H-255, selection toward a crystalline endosperm was accompained by a reduced lysine and tryptophane level as well as a lower biological value when fed to rats.

The current program emphasizes selection toward an "almost flint" grain type; laboratory analyses are used to confirm the enhanced lysine levels. To concentrate modifiers in desirable germ plasm, we are planning to put the opaque characteristic into as many genetic backgrounds as possible, and then select for quality and a hard endosperm. Early success in these selections indicates that a commercial version of opaque-2 with a more acceptable grain type may be available soon.

**2. Effects of climate on protein quality.**

The cooperative study with Purdue University on protein quality was mentioned earlier. This research has been through one cycle in Turipana and in Palmira. In 1972 we will get quality data from ears harvested in two seasons in Turipana and Palmira, and one extended season in the highlands near Bogota. Instruments have been installed in all three locations for light energy measurements, and this climatic information will be related to maturity and quality data.

**3. Further nutrition work with maize.**

In collaboration with ICA, the swine program has carried out extensive tests of floury-2 maize and the combination of floury-2 with opaque-2. In all tests, the floury-2 gene either alone or in combination with the opaque is inferior to the commercial opaque hybrids. There is no apparent advantage to continuing study of floury-2 materials. More detailed results are presented in the Swine Production Systems section. Continuing research with swine will evaluate new and promising maize selections developed by the breeding program. Lifecycle feeding studies (see Swine) will continue to study the long-term effects of a diet with opaque-2 maize as the major or only source of protein. Other protein sources are being evaluated in terms of their value to supplement an opaque-2 maize diet. Nutritional evaluation of sorghum will follow our identification of selections which are well-suited for the weathered soils of the llanos where maize may not be profitable.

TABLE 2. **Seed of opaque-2 maize distributed by the National Seed Production and Marketing Agency of Colombia, 1968 to 1971.**

| Year | Tons Sold | Hectares Planted | Families Benefitted |
|---|---|---|---|
| 1968 | 2 | 100 | 250 |
| 1969 | 8 | 500 | 400 |
| 1970 | 40 | 2,000 | 8,000 |
| 1971 | 230 | 13,200 | 52,800 |

## PROMOTION OF OPAQUE-2 MAIZE

Opaque-2 maize in Colombia is being promoted by an inter-agency committee. Primarily an ICA activity, this project has been supported in part by CIAT and from UNDP funds, administered by CIMMYT. Numerous Colombian agencies have participated in field trials, nutrition research, consumer acceptability studies, and promotional activities. Seed sales and hectares planted have shown a striking increase since the introduction of this maize in 1968 (Table 2).

## TRAINING IN MAIZE IMPROVEMENT AND PRODUCTION

Maize breeders from Ecuador, Haiti and Honduras participated in the improvement and physiology program in 1971. Ten students from the Faculty of Agronomy, National University, worked with the maize program during vacations and between semesters. In addition to this full time in-service training, the maize programs in CIAT and ICA organized a month-long intensive course in breeding in June. The objective was to share experiences and bring new information to a group of breeders, each with one to four years of experience in maize. Ten participants shared in the planning, prepared lectures, and evaluated the series of conferences. Outside participants from ICA, CIAT, and other institutions presented topics. A series of specialized reference books on maize improvement and genetics was distributed. This type of intensive training proved valuable to their work; more valuable experience could come from specialized courses that focused on fewer topics. These will be organized in the coming year.

Future trainees will receive experience in maize production before dedicating full time efforts to breeding or other specialized fields. This practical experience in crop production will help orient their research interests and activities toward the real problems faced by the farmer, and better prepare agronomists who can first grow a crop well, and then concentrate on improvement, physiology, protection, or fertility work.

The maize team has participated actively in the training program in crop production. Seminars in breeding, growth and development, physiology, protection, nutrition, economics, and engineering have been prepared and presented to the trainees. CIAT participation in these classes includes senior scientists, research associates and assistants, as well as trainees.

**Training of young scientists receives high priority in the maize program.**

Field discussion among specialists from INIAP (Ecuador), CIMMYT (Mexico) and ICA-CIAT (Colombia).

The IV Andean Zone Maize Conference was held in Palmira in November, 1971; field trips showed maize and sorghum crops in the Cauca Valley.

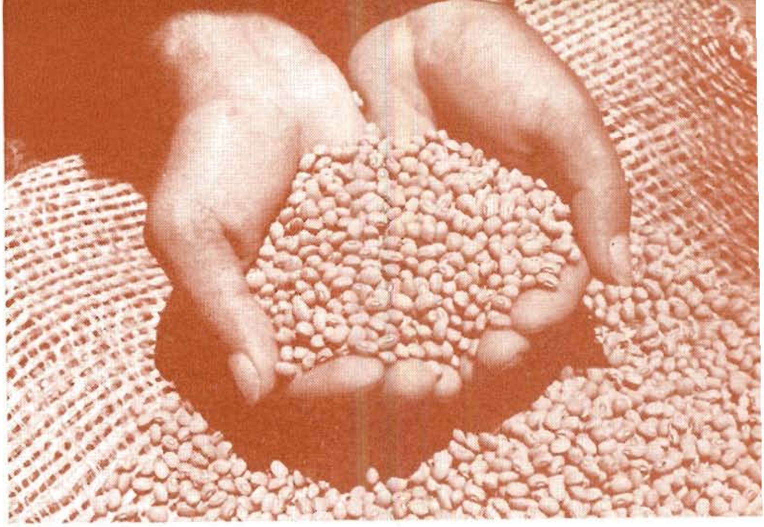
## MAIZE INTERNATIONAL ACTIVITIES

The IV Andean Zone Maize Conference was held in Palmira in November, hosted by ICA and CIAT. More than 50 participants from 12 countries presented formal papers and discussed topics in round table sessions dedicated to improvement, physiology and agronomy, plant protection, nutrition, economics, and sorghum. The group decided to meet each year in different locations in the zone. A second plan to have a general conference every two years, and a more specialized workshop in the alternate years, will also be considered. CIAT is coordinating regional trials within the Andean zone, and will continue to serve as a source of information, reprints, and germ plasm for national programs. A bimonthly newsletter will be published starting in 1972. A joint team from CIAT and CIMMYT evaluated the national programs in Colombia and Ecuador in 1971.

Coordination of research projects and other cooperative ventures require frequent travel in Colombia and the zone. Senior scientists working with maize have traveled to Ecuador, Peru, Bolivia, Venezuela, Brazil, Central America and Mexico during the past year. In addition, they have attended meetings in California, New York, Miami, the Philippines, Nigeria and Mexico and presented research results from the maize projects detailed above. Research assistants and trainees have worked in Carimagua, Turipana, Tibaitata, and other ICA stations in Colombia as part of their research and training activities. These cooperative research projects and travel are the core of CIAT's international work, and provide an avenue for moving germ plasm and sharing ideas throughout the Andean zone and the tropics.

# Food Legumes

## Production Systems



The objective of CIAT's limited work in food legumes is to assist in the development of more and better quality protein for people in the Americas, Asia and Africa who cannot acquire it from animal sources.

The adult requires approximately 14 percent protein for his maintenance diet. The food legumes, or pulses, have a high level of protein in the edible seeds. Percent protein varies from about 15 to 45 percent. However, grain yields have persistently been quite low in comparison to cereals. With the increases in production of wheat and rice, the market price for these commodities has tended to be more favorable for the consumer, and for the farmer who can produce considerably more per unit area of land. The net effect is that there is less food legume production, and fewer people are getting the plant protein provided by food legumes.

CIAT has begun work in food legumes principally with dry beans (**Phaseolus vulgaris**) and soybeans (**Glycine max**) and to a limited extent in cowpea (**Vigna sinensis**) and mung bean (**Phaseolus aureus**).

### RESEARCH ACTIVITIES

#### Dry Beans

Three thousand eight hundred and eighty plant introductions were received from the United States Department of Agriculture for observation, selection and increase. Through cooperation with the Instituto Colombiano Agropecuario (ICA), plantings have been made at Palmira and Medellin. Thirty-two characters, including morphological characters and disease reactions, have been recorded on all lines in at least one semester of growth. Entire entries and individual plants within entries are being selected and replanted, where selection is again practiced. A nursery of reasonably healthy plants demonstrating diversity of characters and promise is being assembled.

#### Soybeans

A thesis study to examine the heritability of time to flowering and length of growing period is now in the $F_3$ generation. Parents in the two parallel studies include one parent with demonstrated yielding ability and generally good agronomic characters crossed with a plant introduction originally acquired from the Ryukyus Island group. The two parents of the former group respond to the environment at CIAT much as do most of the varieties from the United States: relatively short, early flowering, early maturing plants. The plant introductions flower and mature considerably later. Whereas the U.S. material flowers between 25-35 days, the two plant introductions flower about 45 and 85 days after emergence.

It is possible to increase yield in current production systems by genetically delaying the date of flowering, allowing the plant to grow larger before reproduction, and delaying the date of maturity. By setting these two character changes as goals, we also expect to get a taller plant, pods that form higher off the ground and increased seed yield.

One of the plant introductions used as a parent has demonstrated resistance to certain insects in the United States, particularly the Mexican bean beetle. Because of its extremely strong photoperiodic flowering response, crossing in the U.S. latitudes has been difficult. A breeding project including 22 determinate, southern U.S. varieties and this plant introduction is underway.

In cooperation with the maize personnel, initial photoperiodic screening has been started to seek insensitivity to photoperiodism. To date, none is known to exist. There are, however, degrees of sensitivity, and selection for low sensitivity will be practiced.

**Cowpeas**

Cowpeas, along with soybeans and dry beans, have been sent to the eastern llanos of Colombia for observation in the environment at the research station near Carimagua. In this environment of acid soils and occasional drouths, the cowpea holds considerable promise. In an experiment with three levels of lime application and control (6.0, 2.0, 0.5, and 0 tons $CaCO_3$ per hectare), the highest lime application resulted in greater plant development. Despite the soil and moisture regimes, the cowpea varieties did grow and produced a respectable yield under the 0 and 0.5 lime treatments.

Fifteen hundred lines of cowpea are being screened at the ICA Marconia station near Santa Marta. Promising lines will be planted at CIAT with selections being made for disease resistance and yielding ability.

**Mung bean**

Fifty promising lines of mung bean were received from the University of Missouri for growth and observation. Although the vegetative growth is not terminated at this moment, it is evident that the plants and seed production will be small.

**Rhizobium**

A soil microbiologist joined the CIAT staff in May, 1971. Field and glasshouse studies are now underway to determine which bacterial cultures are most effective in the symbiotic relationships with various legume species such as **Phaseolus vulgaris, P. aureus, Glycine max, Arachis hipogea,** and **Cajanus cajan.** Field surveys are being undertaken to examine the distribution of rhizobia in the soil and the effectiveness of native strains.

Investigations are in progress to determine the potential of various carrier media for inoculants. Improvements in carrier media will mean extension of distances and areas served by suppliers

**Soils**

Micronutrient studies at CIAT incorporate three varieties of soybeans and three of dry beans. In the high pH soils, zinc is the most limiting micronutrient. Iron, manganese, and boron all gave slight responses. The soybeans respond more to treatments than do dry beans.

**Plant protection**

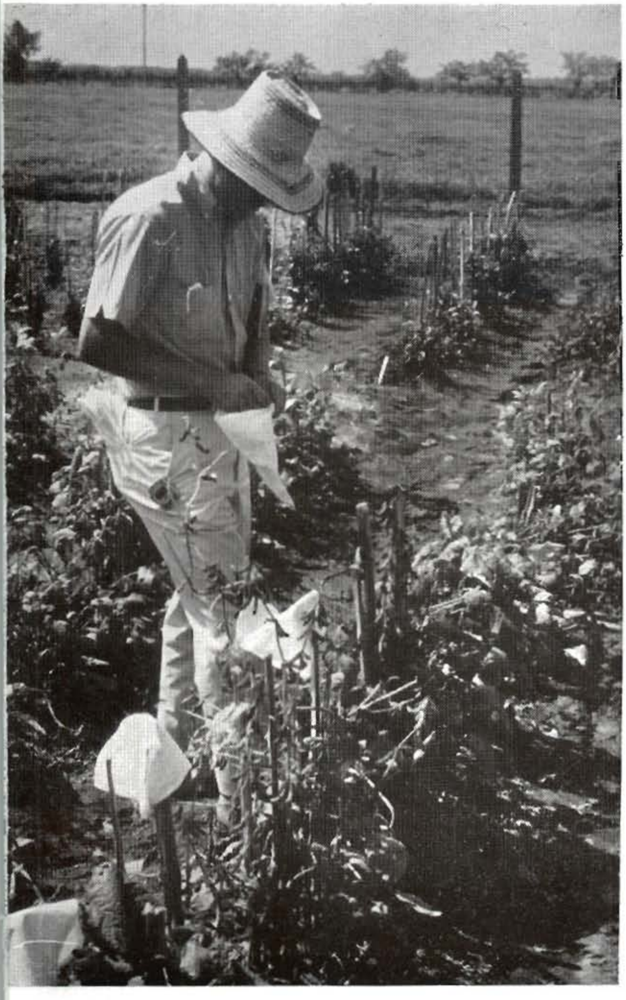
Plant protection studies with herbicides have been started. Soybeans and particularly dry beans are extremely poor competitors with other plants. If we can determine the best weed control combination, yields will improve.

TRAINING

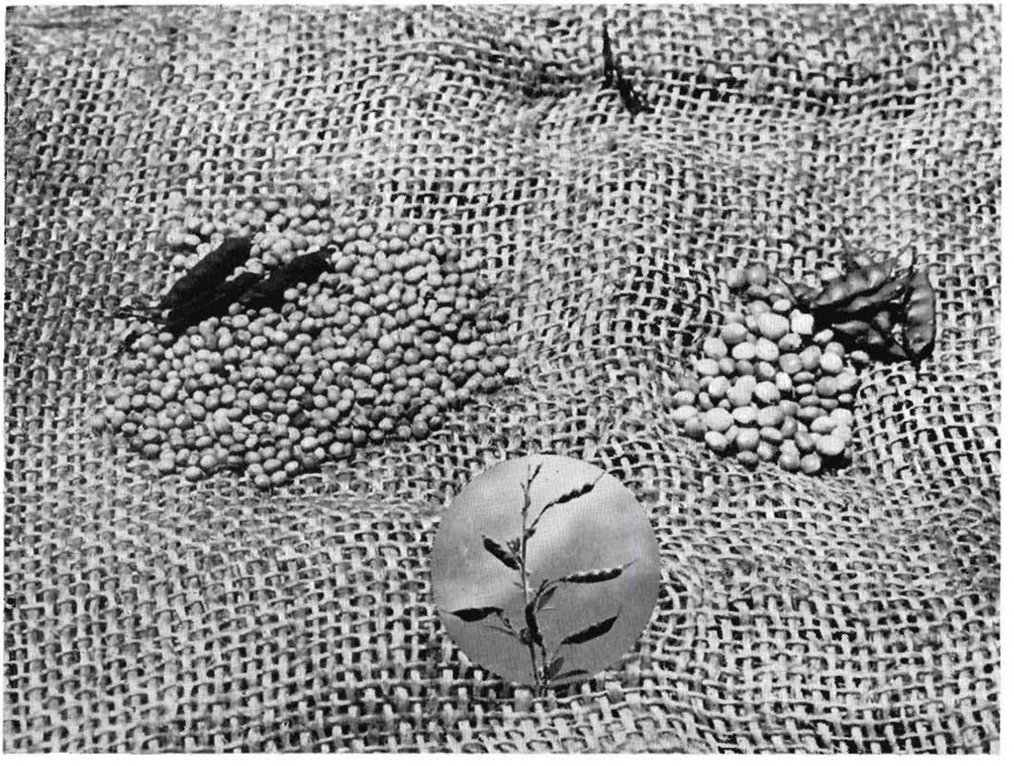
Training is provided promising young scientists. One trainee working with the program is now a research assistant with CIAT. Another is being trained in breeding/physiology of soybeans.

Technical assistance in agronomy, physiology and breeding has been given to the production trainees to help them became familiar with the cultural methods, strengths, and weaknesses associated with dry bean and soybean production.

Food legume plots are frequently observed to isolate desirable plant characteristics under tropical conditions.



Breeding and selection practices are important elements in CIAT's soybean improvement program. A specialist makes an evaluation within $F_1$ generation plants.



Pigeon pea (Cajanus cajan) produces well even under a minimum of technology. Dry seed (left, with representative pod) can be used as a food substitute for field beans, yielding 3 tons/ha, more than twice that of field beans. Green grains (right, with representative pod) can substitute green peas. Reproductive element of Cajanus plant is in circle.

# AGRICULTURAL ENGINEERING and STATION OPERATIONS

The Agricultural Engineering group was occupied in training agricultural engineers in station development, station operations, and commodity programs, support and general administrative functions.

From May to August, 1971, four third-year agricultural engineering students from the Universidad del Valle and three fifth-year students from the National University, Faculty of Agronomy, in Medellin were placed for work experience in the positions of: helpers to tractor drivers, mechanics, topographers, irrigationists and labor supervisors.

Six graduate agricultural engineers also participated in a work training experience from June until December. One of these is now employed by Instituto Colombiano Agropecuario (ICA) in a tropical experiment station, one by Instituto Colombiano de la Reforma Agraria (INCORA) in irrigation and drainage projects, and one assisted in the design and development of the Boliche station in Ecuador and has been employed by the Universidad del Valle to guide agricultural engineers in the training experience. The others are still in training.

The training technique has been to place the trainee with a qualified tractor driver, mechanic, topographer, labor supervisor, and field engineer. He acts first as assistant and then occupies the position before moving to the next position. Time in any position varies from a few days to five weeks. A report by the trainee on his individual work experience is requested and certified. These reports then serve as a reference and record of experience. The desire is to develop responsibility in the trainee and to emphasize interdependence of the supervisor and supporting workers, so that the trainee may appreciate the need for decision making and responsibility and the need to select, train, stimulate and guide skilled personnel to carry out the operations.

### Station Development

Development of the CIAT station has continued through 1971; aerial photographs of the station were made January, 1970 and December, 1971. These show the change in status, as well as soil problem areas.

### Production Systems

Any agricultural production system requires development, maintenance, and operation of land area, roads, irrigation, drainage, shops, and machinery facilities by competent personnel in order to produce a crop. A major portion of time has been devoted to producing commercial scale and experimental crops by the use of the best available information. Records of work inputs have been kept on individual fields, and machines were used to obtain cost and output. Farm equipment work has been divided into 33 classifications with time and fuel consumptions reported in records of

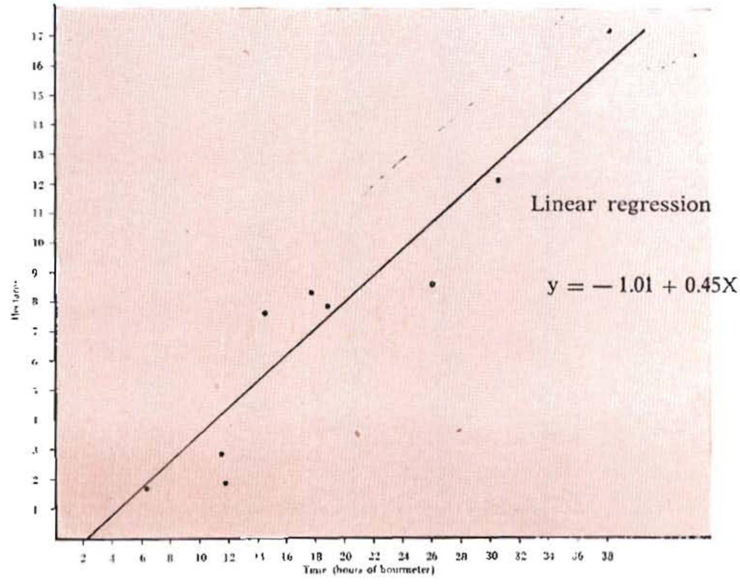



FIGURE 1.— Hectares plowed per hour of hourmeter of a IH 856 tractor with a reversible plow of four 28 - inch discs.

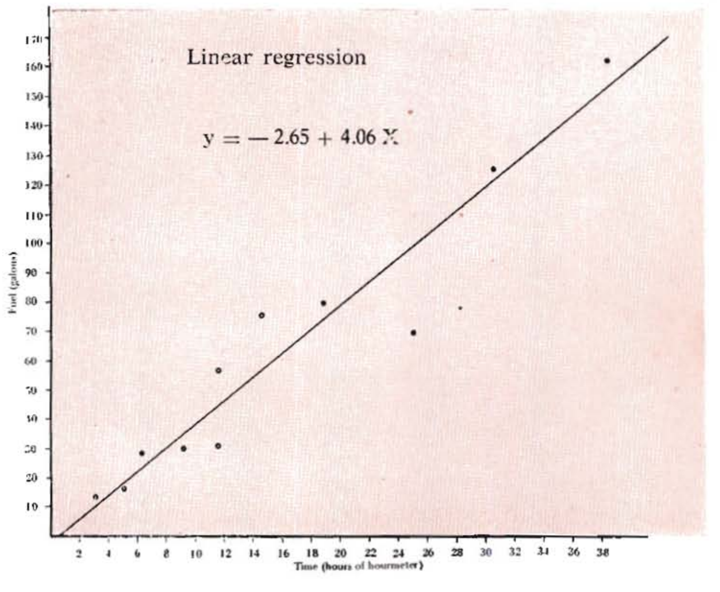



FIGURE 2.— Diesel fuel consumption per hour of hourmeter of a IH 856 tractor with a reversible plow of four 28 - inch discs.

repairs and hours worked; type of work has been kept by individual tractor units. Figures 1 and 2 illustrate types of data obtained.

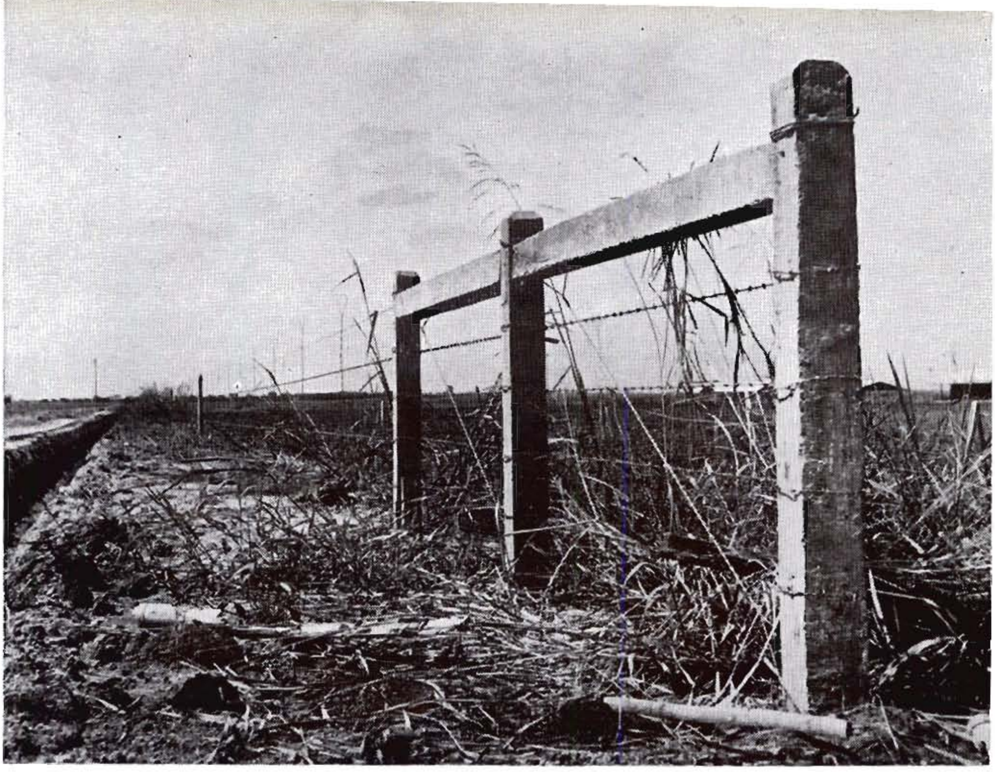
Since machinery is the exception rather than the rule, and corn, cassava, and food legumes are mostly grown without mechanization, we classified various routine labor operations into 30 standard labor contracts. These are used to maintain and operate the experimental station areas and crop production systems. A balanced utilization of labor and machines to produce food crops is an essential part of any production system in the lowland tropics. The need for food and employment are both critical. Properly used machinery will increase both food production and employment. The most efficient use of machinery is in land preparation, transportation, land development, irrigation, and drainage.

One of the major problem areas in the tropics is lack of machinery and labor systems to plant crops during the rainy season. Because 1971 was an unusually wet year there was little opportunity to plant rice under saturated soil conditions since the dry land preparation and seeding of other crops proved impractical.

The lack of suitable equipment prevents easy implementation of the wet land preparation system so widely used in the rice-producing areas of Asia. The vast, poorly drained areas of Latin America should be the best producing areas. Malaria, and the absence of a draft animal such as the water buffalo, have led to the under-utilization of these potentially most valuable areas.

From November, 1970 until January, 1971, the agricultural engineer served as a consultant to the World Bank in the evaluation of a loan to support the development of agricultural research centers in Spain.

In March, July, September, and October, he visited Ecuador to assist Instituto Nacional de Investigaciones Agropecuarias (INIAP) in the development of the tropical agricultural research stations at Boliche, Pichilingue and Puerto Viejo, with major emphasis on Boliche.



Sections of long span fencing used on CIAT farm.

# AGRICULTURAL ECONOMICS

The Agricultural Economics Program is an integral part of the overall CIAT program. Economic studies that complement the various commodity programs (see commodity program reports) are underway for all commodities except legumes. Major emphasis is being given to the economics of production problems relating to each commodity, but marketing problems are also considered. Special attention is being given to the economic consequences, i.e., effects on prices, income distribution, investment, employment and foreign trade of increased production of the CIAT commodities and others that are close substitutes for them.

This section reports only those activities carried out by the agricultural economists which do not logically fall under one of the commodity program reports.

**Farm labor study**

Intensive use of labor characterizes a good deal of agricultural production in the lowland tropics. At the same time the absolute number of rural people continues to increase although the proportion of rural to urban population declines. Consequently there are problems of particular socio-economic importance related to the agricultural labor market.

A study was carried out in collaboration with the University del Valle to estimate the impact of increasing agricultural production on rural employment and wages.

Data on rural wages during 1967-71 were gathered from various regions of Colombia with the cooperation of the Caja de Credito Agrario. Information on rural employment, agricultural production and wages for 1950-70 were obtained from secondary sources.

The rural labor sector received only a small part of the increase in the total revenue obtained by the agricultural sector during the period studied. The increase in total rural labor remuneration was almost matched by the increase in employment, hence average real wages per worker stayed about the same during the five-year period 1967-71. It should be noted that agricultural production expansion was small during the period considered. Hence, the conclusions of this study may not be valid under rapid production expansions.

**Economic impact of new technology**

A study is in progress to estimate the impact of rapid expansions in the production of selected agricultural commodities on certain key factors such as prices, incomes, income distribution, investment, employment and foreign trade.

While agricultural research and extension may aim at increasing production, the ultimate goal of these activities must be to improve social welfare of the people served. Hence, to orient research, extension and public policy so as to maximize the contribution to social welfare, it is considered important to understand the impact of production increases on the above mentioned factors.

A mathematical model to estimate the impact of rapid production expansions on these variables is being developed. Major emphasis is placed on developing a framework by which the distribution of benefits from the introduction of new technology may be estimated under alternative public policies.

As a first step to obtain quantitative information for the model, a study is being carried out to estimate income, price and cross elasticities for certain selected food products.

Data were obtained from a survey carried out among 300 families randomly selected from the metropolitan area of Cali, Colombia. Each family was interviewed in January, 1969 by a Michigan State University research team[1] and again in August, 1970 by a CIAT team. The families were organized into five economic strata according to the following monthly incomes:

| **Strata** | **Monthly income ( Col. $ )** |
|---|---|
| I | 0 - 750 |
| II | 751 - 1000 |
| III | 1001 - 2000 |
| IV | 2001 - 3000 |
| V | 3001 and up |

Even though the data have not been analyzed, preliminary results have been obtained for income elasticities with respect to the commodities included in the overall CIAT program (Table 1).

The income elasticity shows the percentage change in demands associated with each one percent change in consumer incomes. The measure is useful in estimating future demand increases caused by changes in incomes. If, for example, it is predicted that consumer incomes will increase by three percent, the associated percentage increase in demands is given by the income elasticity multiplied by three.

Table 1 shows that increasing incomes will have little effect on the demand for cassava, maize and rice. Higher income families tend to consume less maize and cassava as incomes increase while low income families tend to increase the consumption of these commodities at a modest rate. The impact of income expansions on the demand for meats is relatively large. Again, low income families tend to spend a larger proportion of their income increases on meats than do high income families.

The magnitude of the income elasticity with respect to any one commodity

1. See: Harold Riley *et. al.* Market Coordination in the Development of the Cauca Valley Region - Colombia, Latin American Studies Center, Michigan State University, 1970.

TABLE 1. **Estimated income elasticities for five food commodities in Cali, Colombia by economic strata.**

| Strata | I | | II | | III | | IV | | V | |
|---|---|---|---|---|---|---|---|---|---|---|
| Period | 1969 | 1970 | 1969 | 1970 | 1969 | 1970 | 1969 | 1970 | 1969 | 1970 |
| Cassava | 0.26 | 0.28 | 0.33 | 0.36 | 0.28 | 0.28 | —0.78 | —1.09 | —1.41 | —1.03 |
| Rice | 0.22 | 0.35 | 0.59 | — | 0.65 | 0.49 | 0.59 | 0.37 | 0.23 | 0.25 |
| Maize | 0.19 | C.19 | 0.25 | 0.44 | 0.38 | 0.39 | —0.25 | —0.22 | —0.33 | —0.45 |
| Beef | 1.16 | 0.91 | 1.66 | 0.76 | 0.92 | 1.09 | 0.93 | 0.66 | 0.66 | 0.55 |
| Pork | 2.61 | 2.42 | 2.07 | 1.04 | 2.09 | 1.65 | 1.61 | 1.17 | 1.13 | 1.13 |

along with the predicted population expansion provides a rough estimate of demand expansions at prevailing prices.

If, because of the introduction of improved production-expanding technology or otherwise, commercial production expands at a rate above the rate of increase in demands, prices tend to fall. The magnitude of the price decrease is determined by the price and cross elasticities of demand. Attempts will be made to estimate these elasticities on the basis of the data collected.

Man is the central component of an agricultural system, whether he is the farmer (right) or the technical advisor.

The continuous growing season in tropical areas permits the simultaneous cultivation of different species of plants under specific systems of agricultural production.

# AGRICULTURAL PRODUCTION SYSTEMS

The intended outcomes of CIAT efforts are commodity production systems, along with the associated informational materials and trained personnel.

The components of a system include the technology, the natural environment in which the system operates, and the people involved, as well as the associated inputs and infrastructures.

An efficient farm enterprise often hinges on the integration of several commodity production systems into a single unit. Such multi-commodity farm units lend themselves to crop rotation, utilization of crop residues and surpluses by livestock, and intensification of labor input while minimizing direct operational and capital expenditures. Further emphasizing the importance of multi-commodity farm systems is the general rule that, as farm size decreases, increased attention must be given to multi-commodity enterprises to achieve a minimum level of living for the farm family.

The initial thrusts of CIAT are directed towards developing commodity production systems for certain crops and livestock species. When an adequate technological base is established, this will help provide a nucleus of production specialists to apply this technology. At the same time, CIAT will continue to explore how these commodity production systems, and others, fit into total farm operations, considering the economic realities of practical farm systems and the possible profit advantages of multi-crop-livestock enterprises.

Solutions for some technological problems can be found outside of and independent of the situations where the technology will be used. But other technological problems are intimately related to and part of the environment and people involved. It is difficult, if not impossible, even to identify let alone solve successfully and permanently such problems outside of the environment and without taking into account the people and the infrastructure.

Consequently, CIAT needs opportunities and resources which will make possible the identification, study and solution, **on location,** of such production problems. This would not substitute for but complement present research efforts. At the same time, it would necessitate close linkage with relevant national agencies for research and other inputs outside CIAT's areas of competence and staffing.

With the eventual identification of specific agricultural situations (environmental as well as social, economic and political), CIAT anticipates that development and test of specific agricultural production systems for these situations will serve as a basis for further commodity studies. In other words, the needs of the agricultural production systems will guide further work on specific commodities. To this end, exploratory work is underway in several environments typical of significantly large areas in other countries of the lowland tropics.

To date, agricultural production systems research has been largely an extension of commodity programs, but relating these efforts to comprehensive farm production systems in so far as possible, and consistent with efficient land, labor and livestock utilization.

Accomplishments include: (1) collection of farm enterprise data through the Livestock Production Specialist Training Program and a recently completed survey of 487 farms (see page 23), (2) staff effort to develop preliminary farm production system proposals for CIAT staff and board critique, and (3) developing of certain "commodity" production system information that relates not only to the commodity, but to comprehensive farm systems.

If, beyond the development of production systems, action agencies accept a responsibility for the dissemination to and acceptance of the systems by farm families, then a concern for the process through which the system is developed and demonstrated in the rural economy becomes relevant.

This suggests a research approach which, from the beginning, involves the families. Such an approach helps insure that they understand what is going on, increases rapport between scientists and the people, encourages farmer participation in the exploration of alternatives, and helps them develop criteria for selecting courses of action among the alternatives. This, in the end, becomes a two-way educational process for the scientists as well as the families and leads both groups to a continuity of programs which might be best characterized as an operational research (or systems engineering) approach.

The success of such an endeavor depends upon research that is relevant, and an approach that is educational and developmental as opposed to promotional. The relevance of the research depends on this approach, as does the acceptance and application of the results.

CIAT has investigated several opportunities to become involved in national research efforts on production systems at the farm level, but has yet to develop a definite plan for doing so or criteria for selecting among or committing resources to these opportunities. These opportunities differ in scope or breadth of subject matter, specificity of objective, involvement of other institutions, and participation of farmers.

Development action programs, such as those being undertaken by ICA in various Colombian locations, offer additional opportunities for programmed and disciplined CIAT participation. Conceivably, CIAT should be able, in concert with national agencies involved, to delineate specific areas in which it would make a direct research input, as well as to outline how the training opportunities for CIAT and other agencies might be maximized.

It should be clearly understood that CIAT's interest and role is cooperative participation in production systems research, with training to follow research developments. While CIAT might advise on strategies and approaches, the national agencies in charge would make the final decision and implementation.

The first step in such a cooperative effort would be to achieve consensus among participating agencies of the goals of the project in terms of the people living on the land. To date, observations and survey data, plus staff discussions, lead to the conclusion that, regardless of the nature or size of the farm enterprise, an agricultural production system should provide the following as minimum goals for the people who live on the land:

1. Career opportunities in agriculture attractive enough to deter or discourage some of the migration of rural people to the cities.

2. Year-round adequate diets, including proteins, fresh vegetables and fruits, and some opportunity for diversity in food intake.

3. Opportunity to produce on a weekly or monthly basis certain crops or animals which, when sold, will provide a regular source of cash income. Depending upon location, this may mean poultry and eggs, milk, pork, vegetables, fruits, fibers, or the products of home industry.

4. With an increase in disposable income, improved levels of housing and associated systems of sanitation plus more adequate educational and health services should become available.

Obviously, CIAT is not staffed, financed, or chartered to undertake such a broad undertaking, but it now appears feasible that it might cooperate, particularly with respect to research inputs, with national agricultural, educational, and health agencies to demonstrate vividly and effectively the methods, potentials, and values associated with the pursuit of such goals by national agencies.

Such an approach would provide CIAT with opportunities for its scientists to study the problems of agricultural production in specific locales and situations, and, in cooperation with national agencies, to conduct field and adaptive trials of new technology to make sure it is technically and economically viable in specific situations.

Rather than stressing a particular type of agricultural system, CIAT has decided to test the system concept in a variety of ways through its ongoing commodity programs in research and training. Both activities provide opportunity to observe the systems which now exist, the attendant problems, and how these might be solved. One such effort with small swine farmers is reported in the Swine section, while the Beef section describes the Livestock Production Specialist Training Program activities. Under Training and Communication, efforts made in 1971 to help crop production trainers learn about the systems and problems of small crop and truck farmers are outlined.

**Small Farms.** Although widely discussed and often cited as an example of what ought not to exist, small farms continue to be the main source of income and market for labor for the rural people of Latin America. Agricultural production systems research should offer new and imaginative ways of increasing cash and real incomes on these farms with a minimum increase in risk. Specifically, production systems are needed that will permit increased productivity with a minimum cash outlay and no increase in the uncertainty of achieving at least a satisfactory minimum level of income. A pending project contemplates an intensive study of a few farms in a rural community to ascertain their needs and expectations so that production systems can be designed to fit requirements. Systems will be developed on small farm size plots at CIAT before taking them out to farm communities. This program would be carried out in cooperation with national agricultural agencies.

**Intensive Crop-Livestock Systems in Fertile Land Areas.** In the more fertile land areas in Latin America, such as the Cauca Valley, present population-land pressure trends would indicate an increasing shift from larger, more extensively managed units to smaller, more intensively managed units. These intensive production systems would likely include both crops and livestock, where food crops would provide cash income, meet subsistence food needs, and at the same time provide crop residues, by-product materials, and surplus grains to support cattle and swine enterprises. Specific crops might be grown to support the livestock enterprises such as cassava or plantain for swine, and sorghum or sugar cane as silage for cattle. The role of locally available by-product materials such as molasses would be considered to complement farm produced feedstuffs.

**Family Operated Ranches.** There are many owner-operated ranches in the Colombian llanos and similar savannah regions of Latin America. Most have limited herds and are developing slowly because of inadequate management and/or lack of capital for the technical inputs. Development and production loans could be obtained in some cases, but poor herd performance offers little promise for repayment of such loans.

CIAT is cooperating with ICA at Carimagua to generate basic knowledge in the areas of animal health, nutrition and reproductive performance and to test production systems based on the best available information relative to livestock management in poor, acid soil areas.

Traditional cash crops can be grown if sufficient lime and fertilizer are applied, but present transportation costs make it difficult for most grain crops to compete on the domestic or world market. Some fruits grow well with little or no lime requirement and apparently modest fertilizer needs. Mango, cashew, pineapple and perhaps citrus could be grown and sold successfully with adequate market arrangements and a processing industry to absorb the surplus seasonal production. Of all the crops presently grown in the llanos, however, the most widespread and easiest to manage is forage. The beef cattle industry accounts for the only significant production in the areas outside the piedmont around Villavicencio.

Cattle ranching is commonly thought to be for the wealthy; but perhaps it is possible that family-operated ranches could be the basis for the colonization of some of South America's vast savannahs.

To test this hypothesis, CIAT scientists have been developing models for family-operated livestock units in the smooth, well drained savannahs of Meta and Vichada in the Llanos Orientales. One such model is here described.

The model has a herd of 50 producing cows for a total of approximately 90 animal units on 100 hectares. This is not necessarily an optimal size, but it is feasible.

This model develops to full size over 12 years, starting with 15 cows and one bull. An important part of the plan is the subsistence base of food crops, grains and small animals, largely for on-farm consumption. This base is developed during the first year on three hectares of limed and fertilized land and allows low maintenance costs for the family while the cow herd develops. An initial cash investment of approximately US$3,000 is required for a family starting with no livestock or improvements. An additional US$3,000 is required during the 12 years of development, most of which should be generated by the enterprise.

The gross annual income from sale of livestock at the end of the period is estimated at $3,100, the value of the enterprise to be approximately $15,000. Raw land value is not considered as a cost or asset. Present commercial market value of the land east of the Manacacias probably ranges from US$0.50 to US$5.00/ha, decreasing in value from west to east.

Assumed herd performance of 60 percent weaning rate and 6 percent mortality and pasture carrying capacities are believed realistic, based on current technology. Animals reach market weight at three to four years. Current forage research programs in the area should result in marked improvement in forage quality, improved herd performance, and increased carrying capacity.

For subsistence crops, more assumptions were necessary, but production estimates are believed conservative. Input costs are based on current delivered costs (about US$15 metric ton freight costs) for the various commodities at Carimagua. With improved roads, and completion of the bridge at Puerto Gaitan, these costs will be lowered. Lime costs in particular should decline when the new quarry at El Dorado, south of Villavicencio, is completed.

Preliminary model analysis shows that high commercial interest rates of 14 percent per annum and relatively low herd performance figures which result in slow establishment and low yields will be serious obstacles to overcome in the early stages. Land appreciation, which has not been included, would greatly improve the performance picture.

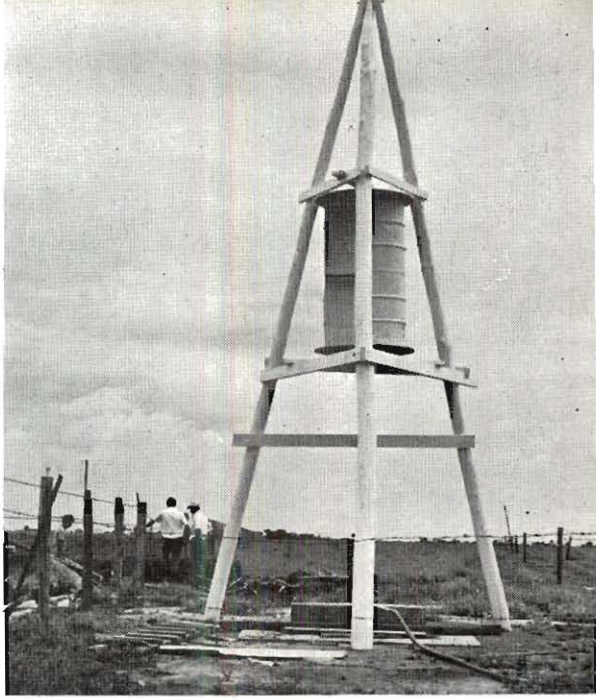
Modifications of this ranch development plan include starting with a larger number of cows or with the 15 cows and their normal ranch complement of heifers, steers and calves, thus reducing the development time.

Most of the components of the model and others which are less intensive are being tested and refined in field trials at Carimagua.

Food and feed grain crops have been screened for low lime requirement as described under Soils, page 103. Improved grass pastures are in grazing trials, Beef, page 19. Low cost, long span fences have been successfully tested. Problems of animal health, mineral, protein and energy supplementation are being studied. Rations based on locally available feeds, such as cassava, plantain, and cowpeas, are being tested in the swine program at CIAT.

**Low Cost Windmill**

Each year thousands of cattle are lost in the lowland tropical savannahs of America for lack of water. In the Casanare region in the Colombian llanos and the western llanos of Venezuela, distances between rivers and creeks (the only sources of water during the dry season) are great; cattle are obliged to



**Water, a scarce component of production systems in the eastern plains of Colombia during the dry season, can be obtained by means of a windmill built from local materials.**

either walk great distances or remain near the water, in which case they rapidly exhaust the forage bordering the streams.

The water table in these regions is rarely more than a few meters below the surface. CIAT, in cooperation with ICA, has intalled an experimental low cost windmill at Carimagua for pumping ground water for domestic animal and possibly irrigation uses. The prototype mill (above) is a modification of a design developed by the Brace Research Institute of McGill University's Faculty of Engineering and tested at its Experiment Station at St. James, Barbados, West Indies.

The simple mill is easy to construct. Locally available materials cost approximately US$125 and include shop work not easily done in the field. This price includes 1 1/4 inch galvanized pipe and steel sucker rod for a 10-meter well, a 3-inch diameter bronze windmill cylinder, locally cut poles for the 8-meter tower, and cement and reinforcement for the well ring, platform and cover.

**A water tank takes form over base of palm sticks wired together with used barbed wire. No forming lumber is required.**

The windmill yields more water than had been expected and is now being considered for irrigation of small (1/2-1 hectare) plots for dry season food production.

**Water Storage**

A low cost water tank was built as a combination storage and stock watering tank to accompany the experimental windmill. The concrete and plaster tank is five meters in diameter and 80 cm deep. The walls were formed with plaster over a base of palm cortex called "choapo" or "macana", cut and wired together with used barbed wire like a snow or picket fence in the form of a circle (above). The floor was poured, thus there was no need for forming lumber, bricks or concrete blocks. The materials cost approximately US$30.

**Construction, Using Native Materials**

To meet urgent housing needs at Carimagua, CIAT designed and built two houses (page 102), using locally available materials where possible. The houses are cool, comfortable and well protected from most insects and other pests. They are complete with overhead water supply, bathroom, septic tank, kitchenette, two bedrooms, living-dining room, covered ground floor slab, laundry area and tool room at a cost of approximately US$1,800 each. This cost would be prohibitive for most settlers in the area. However, certain design features and use of materials can be easily adapted to much simpler and less expensive dwellings.

**Related Soil and Agronomic Research.** Various projects of the soil scientists and agronomists directly relate to general agricultural systems concerns. They have conducted small plot field experiments related to micronutrients in sorghum; lime and phosphorus for upland rice, maize, and sorghum; and the influence of fertilizers and seeding rates on the establishment of forage grasses and legumes. These are reported in the relevant sections.

Soil often has been overlooked as an important ecological factor in breeding programs designed to produce materials of wide geographic adaptation. CIAT is building a base of fundamental information related to chemistry, fertility, and management of weathered soils such as are found in the plains of Venezuela, Colombia, and Brazil. This base will serve for the development of subsistence food crop production systems so that persons living in the area may feed themselves. The same information is also vital for long range commercial crop production plans, and for pasture and forages improvement on these extremely acid, infertile soils.

Work has continued this past year, at Turipana in cooperation with ICA, to identify the production problems in the low altitude, alternate wet and dry areas so typical of much of the lowland tropics. With adequate levelling and drainage completed in one large field, several lowland rotation experiments are now underway. The crops involved in these include maize, soybeans, sorghum, sesame and cotton, the latter crop being one extensively grown in the area.

**Agricultural Engineering and Related Issues.** As information becomes available, agricultural engineers and agronomists are interested in devising ways of putting the results of the experiments and information from other sources together in combinations which will be beneficial to the subsistence farmer, independent small farmer, and agrarian reform projects of various types in tropical areas.

As with the other scientists, they see it necessary to identify the factors limiting production and to test solutions on actual farms. The factors believed to be most limiting on production are: (a) water management, including irrigation, drainage, and soil and water conservation; (b) tillage systems to prepare, plant and cultivate with reasonable weed control; (c) multiple crops to spread the labor requirements and to provide multiple harvests of fruits, vegetables, milk, poultry, fish, swine, and feed for the family and provide a surplus for weekly market income, and (d) transportation to and better market facilities.

To this end, discussions are in progress on the north coast of Colombia for a cooperative project involving INCORA, SENA and ICA for the wet land preparation and planting of rice to use the existing natural conditions. More recently, discussions have been opened with the Cauca Valley Corporation for the study and development of production systems more advantageous for the Cauca Valley and with the possibility of absorbing some of the under-employed population of Cali.

**Coordination and Direction.** Now that the staff of CIAT has grown in size, diversified in commodity thrusts and has grasped the significant potentials to be realized through eventual concentration on agricultural production systems, future developments will depend, to a large extent, upon providing constant, dynamic leadership.

The Board of Trustees has specified that, for the present, this responsibility shall rest with the Deputy Director General for CIAT.

Similarly, if the program is to be truly effective and have opportunity for application and test on real farms, collaboration and cooperation with national agencies is absolutely necessary. As CIAT gains experience with such operations in Colombia, it will seek opportunities to cooperate in similar programs in other countries.

Experimental staff housing at Carimagua built largely from native materials.

Corn responds dramatically to phosphorus at Carimagua site. Phosphorus check plot is shown in center and left foreground; 50 kg $P_2O_5$ treatment is seen in right foreground. Same treatments continue in background but superimposed on 600 kg $P_2O_5$/ha broadcast treatment. Entire plot received 8 tons lime/ha.

# SOILS

Soils research is directed toward the solution of production problems in support of the various commodity programs. Most of the results of this research are reported in the individual commodity chapters. There are, however, certain areas of research that relate to a number of commodities or that have independent significance.

## SOIL MICROBIOLOGY

1. **Culture collection**: Availability of reliable inoculants is a major problem in most of tropical America. A primary objective of the soil microbiology group is to obtain cultures of **Rhizobium** for the forage and seed legumes important to this region. To date some 100 different cultures have been obtained, representing the most effective cultures from Australia, the United States, Rhodesia and Brazil. These have been preserved by freeze-drying and are now available for distribution. It is planned to expand this collection to include organisms of other genera which could be helpful in university training programs. These would include representative genera of bacteria as well as those organisms (i.e., Beijerinckia and blue green algae) which are agriculturally important.

2. **Testing of Inoculants:** Field and glasshouse trials are underway at CIAT to determine which bacterial cultures are most effective in symbiosis with the forage and grain legumes important to this region. Plant species included in those trials are **Arachis hypogea, Cajanus cajan, Colopogonium** sp., **Desmodium uncinatum** and **intortum, Glycine max, Glycine javanica, Leucaena Leucocephala, Phaseolus atropurpureus, P. aureus** and **P. vulgaris**, and **Stylosanthes gracilis**. These trials will be extended to the Llanos Orientales in 1972. When suitable contacts have been made, the testing program will be expanded to neighboring countries. Field surveys are also being undertaken to examine the distribution of rhizobia in the soil, and the effectiveness of the native strains. Highly effective strains are being selected for further comparative tests. Particular attention is being paid to rhizobia from soybean, field bean, **Stylosanthes** and **Desmodium.**

3. **Inoculant supply:** The CIAT soil microbiologist arrived in May, 1971; since then, several farmers have requested inoculant supplies. These have been supplied to promote inoculant usage. About 1,000 acres have been inoculated to date, the inocu-

lant being supplied in the form of broth culture. Inoculant successes have been reported for both the Popayan and Bogota regions in what previously had been regarded as problem soils. Peat deposits have also been located, and these—together with sugar cane bagasse—will be investigated as carrier media for the inoculants. This would allow the cultures to be supplied to a much greater area and would ensure inoculant viability. Contact with private inoculant producers is being established in the region. An initial sampling of commercial inoculants indicates low rhizobial populations. CIAT will collaborate with local producers, offering them a wide range of effective and viable cultures and technical consultation. Quality control should be an essential aspect of this collaboration.

## SOIL CHEMISTRY

**Chemical Kinetics of Flooded Oxisols.** Orange leaf disease (anaranjamiento) has been reported as a serious limiting factor in the production of flooded rice on oxisols and similar poor, acid soils of the lowland tropics. Progress was made during 1971 in describing the disease more precisely and in defining the soil conditions which cause it (see Rice, page 62).

## DIFFERENTIAL SPECIES AND VARIETAL TOLERANCE TO SOIL ACIDITY

Species differences with regard to tolerance to soil acidity are well known. There are a number of forage grasses and legumes that require little if any lime for optimum performance even on soils of pH 4.5 and lower. The responses of such species as **Melinis minutiflora** (molasses grass), **Hyparrhenia rufa** (yaragua or puntero), **Stylosanthes guyanensis, Pueraria phaseoloides, Calopogonium muconoides** and **Desmodium intortum** to small additions of lime are probably due to calcium and magnesium.

Tree species which are well adapted to acid soil environments include: mango (**Mangifera indica**), citrus, guayaba (**Psidium guajaba**), marañón (**Anacardium occidentale**), and ciruela (**Spondias purpurea**).

There are a few annual crops which grow well on acid soils with relatively low lime requirements, including: Cowpeas, peanuts, sesame, sugar cane, pineapple, rice, and cassava. Varietal differences within crop species have recently been defined for wheat, barley, potatoes, tomatoes, and other crops, but as yet little if any work has been done to breed crops for acid soil tolerance.

A screening program has been initiated at Carimagua as a part of the commodity programs with the objective of identifying acid soil-tolerant lines or varieties for use in crop improvement programs and for release for immediate farm use if such tolerance is combined with acceptable agronomic characteristics. Entries are screened at 0, 0.5, 2, and 6 tons of lime per hectare. The low rate of 0.5 ton is included to supply Ca and Mg as nutrients. The six-ton rate is sufficient to neutralize the exchangeable aluminum.

Cowpeas (**Vigna sinensis**) are the most acid-tolerant food legumes screened to date at Carimagua. There are, however, appreciable varietal differences. Sorghum is generally better adapted to acid soil than corn.

A phosphorus x lime experiment with rice (upland) revealed that there is much greater variability in that species as regards acid soil tolerance than had been expected. CICA 4 responded strikingly to lime applications up to 16 tons/hectare (Fig. 1). The lime applications were made 12 months previous to planting the CICA 4. The first crop of rice (IR8) was lost because of late season drouth. There are rice varieties that appear to require little if any lime under upland conditions, including Bluebonnet 50 and Mono Olaya Dorada, two traditional varieties grown in the Co-

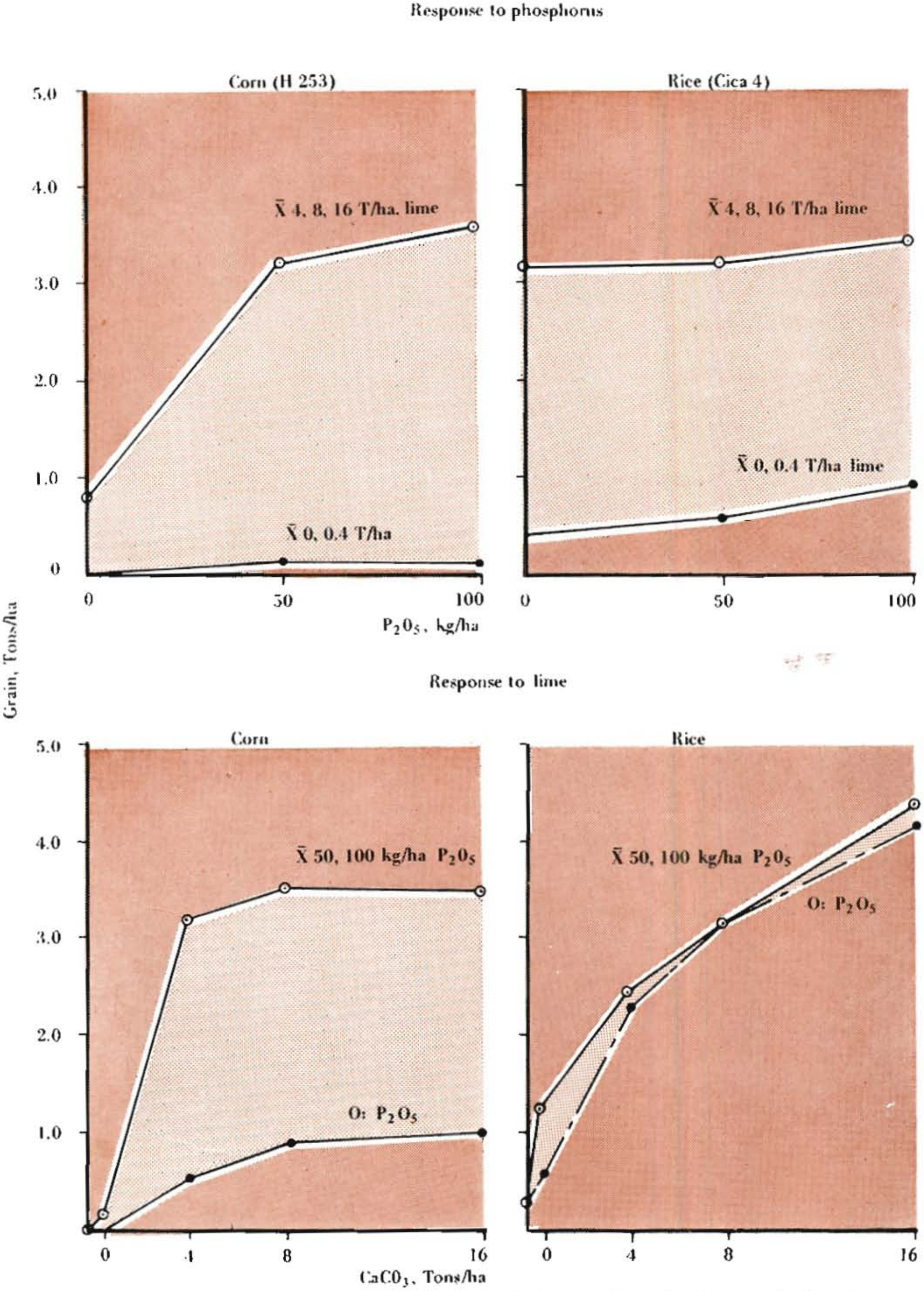



FIGURE 1.— Response of a corn hybrid and rice variety to lime and phosphorus on an oxisol at Carimagua, Colombian Llanos Orientales.

lombian llanos. A large number of lines and varieties will be screened.

## SOIL FERTILITY

**Phosphorus Availability:** Corn was grown in a parallel phosphorus x lime experiment with similar lime response but strikingly different phosphorus response (Fig. 1 and lower photo, page 102). Corn responded strongly to phosphorus at lime levels of 4, 8, and 16 ton/ha, while CICA 4 responded slightly only at low levels of lime. The indication is that the native soil phosphorus is much more available to the rice than to the corn. The lack of response to P in the case of rice is difficult to explain in view of the extremely low P levels in the soil (2-3 ppm P, BRAY II). The corn experiment was limed six months prior to planting. The rice suffered from a severe attack of blast (**Pyricularia**), which was accentuated at high P levels. This only partially explains the results since yield levels were relatively high for upland rice in spite of the **Pyricularia.** All corn experiments have suffered heavy damage from insect attack (bud worm, stem borer and earworm among others) in spite of frequent and regular spraying.

## MICRONUTRIENT DEFICIENCIES

A series of micronutrient trials has been conducted in the greenhouse and fields at CIAT. Zinc, boron, and iron have been identified as the most serious limiting factors. Boron is the most widely observed deficiency in corn, sorghum and grain legumes and appears to be almost uniformly deficient on well drained as well as poorly drained soils. Zinc deficiency is most serious in rice (See page 51). Preliminary results from trials with zinc, boron, iron, and manganese are reported on Page 65.

In addition to expected species differences there are striking varietal differences within species relative to susceptibility to micronutrient deficiences. These differences were previously reported for boron in sorghum and have now been confirmed for zinc in rice and for zinc and boron in soybeans and field beans.

Two micronutrient trials at Carimagua with sorghum and one with peanuts indicate that initially, and at the yield levels obtained (approximately 3.0 and 1.5 ton/hectare, respectively), no one micronutrient is seriously limiting. Corn appears to suffer from Zn deficiency and that element is being included routinely in all field trials at Carimagua. Old citrus trees at the ranch headquarters show a complex of deficiency symptoms including boron and zinc.

## TRAINING

The soils staff has participated in the Crop Production Specialist Training Program both in the lecture room and in the field. The trainees have actively participated in the planning and execution of micronutrient trials on high pH soils at CIAT.

A postgraduate intern is in training at Carimagua as part of the soils and crops team. The research at Carimagua has been significantly complemented by the work of two doctoral candidates from Cornell University. One student lived at Carimagua for eight months while conducting field research on "anaranjamiento" of rice. The other conducted field research with corn and sorghum on lime and phosphorus response and interaction.

A Colombian doctoral candidate at North Carolina State University sampled soil profiles at Carimagua and other sites in the vicinity and did extensive laboratory work in characterizing those profiles with mechanical, chemical and mineralogical analyses. These results are published in the doctoral thesis of Ramiro Guerrero.

An undergraduate student from Purdue University worked with the soils and rice groups for six months as part of a special training arrangement. The staff cooperated in setting up and carrying out a travel and study program for a class of Purdue University undergraduates studying international agronomy.

# TRAINING AND COMMUNICATION

Training and communication are integral parts of all CIAT operations. The specific individuals and organizational units which comprise the professional group, Training and Communication, cooperate and collaborate with the other professional groups and commodity programs.

Through its training, conference, and informational activities, this professional group assists CIAT to develop and maintain an international network for agricultural research and development.

Because of the commodity task force orientation of CIAT, most of the activities relating to training and conferences are reported in the specific commodity sections. The purpose of this chapter is to provide an overall review of the range of activities and to report, in detail, such aspects and events that are not specifically related to commodity programs.

**Training**

Initial training activities were limited by the lack of physical facilities, but during the period July 1, 1968 to December, 1971, 137 persons from 15 countries had been enrolled in various training activities (Table 1). These included 36 who completed training in 1971. (For complete list of the 82 in training in 1971, see Table 2.)

CIAT has established among its training categories that of the post graduate or in-service intern, to provide direct, on-the-job agricultural research experience for young staff members of national research institutions. Such research training is oriented to the identifying and solving of problems limiting production.

As many livestock and crop production problems can be resolved by adapting and applying existing or new technology and management techniques, a production specialist is required. He becomes a link between the specialist and the producer, an individual capable of applying production packages and conducting practical research and field trials in local environments. CIAT hopes to create such specialists through its livestock and crop production specialist training programs.

Over time, the staff expects an integration between the research and production specialist training programs, including the possibility of some research trainees spending time learning or improving their production capabilities.

Arrangements exist with the National University of Colombia and the University of Valle, Cali, for cooperative academic and research programs through which some CIAT trainees, known as research scholars, each year work to-

TABLE 1. **Trainees processed by CIAT classified by field of specialization July 1, 1968 - December 31, 1971.**

| Trainee Category | Field of Specialization | | | | | Total |
|---|---|---|---|---|---|---|
| | Animal Sciences | Plant Sciences | Agricultural Economics | Agricultural Engineering | Communication | |
| In-Service Trainees | 12 | 37 | 4 | 8 | — | 61 |
| Production Specialists | 12 | 32 | — | — | — | 44 |
| Research Scholars | 4 | 2 | — | 2 | 3 | 11 |
| Research Fellows | 1 | 3 | — | — | — | 4 |
| Special Trainees | 4 | 4 | — | — | — | 8 |
| Doctoral Candidates* | 6 | 1 | — | — | — | 7 |
| Travel Support Only | — | 2 | — | — | — | 2 |
| TOTAL | 39 | 81 | 4 | 10 | 3 | 137 |

* Supported by Others.

ward advanced degrees. In addition, a limited number of research scholars are supported fully or partially in master's degree programs in other countries.

CIAT continues to explore arrangements with graduate level funding organizations in various countries whereby doctoral candidates at universities in the developed countries may do their dissertation research on agricultural problems of the lowland tropics under the direction of CIAT scientists. Several such projects are now underway. Normally, such persons are appointed as research fellows. Some individuals in this category are not necessarily involved in academic programs and may concentrate on a specific research problem important to CIAT.

**Crop Production Specialist Training**

Young graduates of agricultural colleges throughout Latin America are chosen for the Crop Production Specialist Training Program. These agronomists often lack socio-economic and technological experience in producing crops and in direct involvement with farmers and farm problems. CIAT provides such trainees with the opportunity to test their theoretically-oriented university training, and gives them practice in all aspects of farm management and the growing of crops using the varying levels of technology available to both small farmers and larger producers.

The first crop production specialist course began on June 15, 1970 and ended July 29, 1971. Ten Colombian agronomists participated. The second course began March 8, 1971, and will continue until the end of February, 1972, and is composed of 14 trainees from the Dominican Republic, Honduras, Costa Rica, Panama, Colombia and Ecuador. This staggered course scheduling offered trainees of both courses a five-month period of joint training, in which the older, more experienced students helped guide and orient the new students in the learn-by-doing methodology on which the course is predicated.

During the year, 29 CIAT scientists and 16 professionals from cooperating Colombian institutions and private concerns provided more than 500 hours of classroom instruction through lecture-discussion sessions in crop science and technology, economics, farm administration, production cost accounting, and communication.

The trainees worked under supervision, in the fields at CIAT, growing rice, maize, sorghum, soybeans, field beans, and cowpeas. They were then assigned "small farms" of 9-12 hectares within the CIAT farm, which they managed in groups of three or four. The trainees were responsible for managerial decisions, the inputs to be used, and the machinery required.

At the end of the course, these groups reported on their projects, showing bases for planning and cropping decisions, an account of technical observations and problems encountered during the growing season, a detailed breakdown of production costs, and an economic analysis of the "farm" profitability in terms of inputs, production costs and sales of crops.

An essential part of crop production training is the methodology of conducting replicated trials of field crops to evaluate the applicability of research at experiment stations for commercial farming enterprises. Throughout the year, trainees carried out such trials, both on their "farms" and in the communities in which they worked.

During the year, trainees participated in two separate exercises in living with, learning about, and assisting small and subsistence farmers in the Cauca Valley. The first experience grew out of a classroom exercise within the communication instruction. Groups of four and five trainees spent three days per week during the month of July in four small communities helping farmers in their daily tasks and discussing their problems.

They subsequently prepared a report giving background information on the families with whom they had worked, an analysis of problems encountered, and recommendations for assistance. These reports were presented to both instructors in the course and members of the CIAT staff, who were invited to participate in the discussions and offer suggestions. Through such experience and interaction, researchers are confronted with the most pressing problems facing these lower-income rural peoples, and students gain practice in serving as a link between the research scientist and the small farmer.

The second field activity during 1971 placed the trainees two days per week for six months in one small community

TABLE 2. **CIAT trainees appointed and/or completed training January 1, 1971 to December 31, 1971 by field of specialization and category of trainee.**

| | Category of Trainee | | | | | |
|---|---|---|---|---|---|---|
| | In-Service | Production Specialist | Research Scholar | Research Fellow | * Special Trainees | Total |
| Livestock Production | — | 3 | — | — | 1 | 4 |
| Pasture & Forages | 7 | — | 1 | — | 2 | 10 |
| Swine | 2 | — | 1 | — | 2 | 5 |
| Animal Health | — | — | 2 | — | 4 | 6 |
| Rice | 6 | — | — | — | — | 6 |
| Maize | 1 | 1 | — | 1 | 1 | 4 |
| Cassava | 1 | — | — | 1 | — | 2 |
| Food Legumes | 2 | — | — | — | 1 | 3 |
| Crop Production | — | 21 | — | — | — | 21 |
| Soils | 1 | — | — | — | 2 | 3 |
| Plant Pathology | 1 | — | 1 | — | — | 2 |
| Entomology | 2 | — | 1 | — | — | 3 |
| Weed Control | 1 | — | — | — | — | 1 |
| Agricultural Engineering | 6 | — | 2 | — | — | 8 |
| Agricultural Economics | 2 | — | — | — | — | 2 |
| Communication | — | — | 2 | — | — | 2 |
| TOTALS | 32 | 25 | 10 | 2 | 13 | 82 |

* These figures include Texas A&M students, doctoral candidates supported by others, and those trainees receiving travel support only.

in the Cauca Valley (El Bolo). Each trainee provided direct technical assistance on two to four small farms. At the end of their training, the students will present reports of their work with the farmers, along with suggestions for continuing technical assistance.

As a part of this project, the trainees invited cooperating farmers to visit the CIAT farm for one day in mid-November. The purpose of this visit was: (1) to give the trainee practice in planning, carrying out, and evaluating a field day; (2) to demonstrate to farmers that the trainees' advice was drawn from their "small farm" experience.

The final two weeks of the course will include, along with examinations, an evaluation of the course activities through a series of round-table discussions with both trainees and instructors on the technological and socio-economic factors involved in crop production systems.

A third crop production specialist training course is projected for August, 1972. The five-month break between the second and third courses will allow the project coodinator and staff instructors to review, evaluate and revise training materials and methodology.

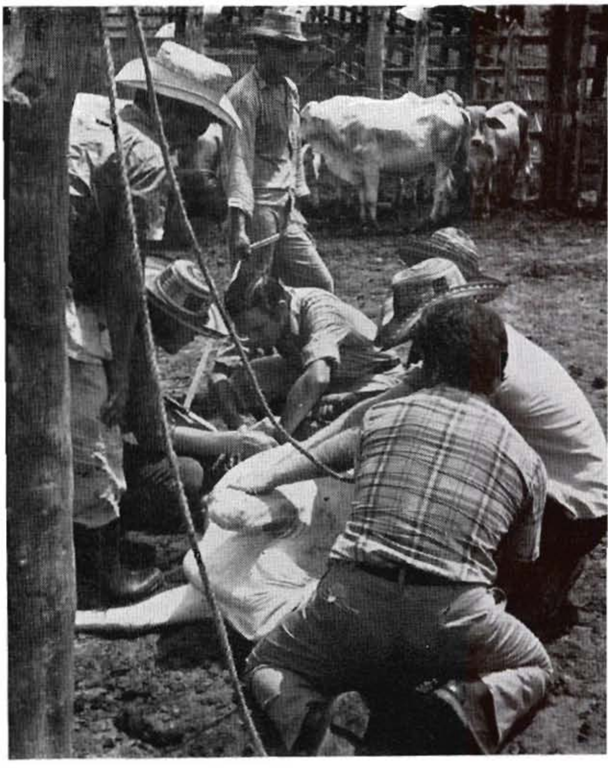
**Related Activities of the LPSTP**

The first CIAT Livestock Production Specialist Training Project ended on December 17, 1970, with the graduation of 11 Colombian trainees.

Project activities in 1971 were directed toward establishing and maintaining contact with the graduates of the first course. Efforts were concentrated on two specific areas of interest: initiation of similar training projects, conducted by graduates of the course, within four Schools of Veterinary Medicine and/or Animal Science in Colombia, and completion of field work and data collection on cooperating ranches in the Sincelejo area, where the first course tcok place.

At the University of Caldas, a former trainee initiated a course in ranch management within the School of Veterinary Medicine. This included a two-week training period at the end of course work on individual ranches in the Sincelejo area for the 27 fifth-year students. Field work was carried out under the supervision of CIAT personnel working in Sincelejo. A similar in-field training program is being planned for 1972, this to take place in the lower Magdalena Valley.

Another graduate of the first course heads the Ambulatory Clinic of the School of Veterinary Medicine at the University of Antioquia, Medellin. Plans are now being made to incorporate a two-month in-field training program into the undergraduate curriculum in



First hand experience in handling animals is one of the crucial skills that livestock production trainees must acquire.

**The 'learning by doing' approach is used in graduate crop production training.**

1972. A similar course and field training is being established, with CIAT assistance, at the National University facilities in Medellin.

Preliminary discussions were also held with the dean of the School of Veterinary Medicine of the National University, Bogota, for possible CIAT cooperation in a training course in livestock production as part of the fifth-year curriculum.

One or more faculty members from each of these institutions is expected to be part of the next livestock specialist training program scheduled to begin June 1, 1972.

Also in the Sincelejo area, three graduates continued the field work, technical assistance and research trials begun on the collaborating ranches. During the year they organized and carried out a course in ranch management for the Veterinarian's Association of Sucre, composed of thrice-weekly, two-hour lectures and discussions over a ten-week period. At the end of the year, one of the graduates left CIAT to accept a position with the Diversification Program of the National Federation of Coffee Growers; another left to begin work as an officer-in-charge of the ICA Livestock Production Program.

Two graduates continue with CIAT, coordinating and assisting in the development of similar courses within Colombian educational and governmental institutions.

Preparation for the second course in livestock production specialist training began at mid-year with the sending of course announcements to Latin American countries as an initial step in the recruitment and selection of trainees. Teaching materials are presently being reviewed and updated for use in the second course. Plans were initiated in late 1971 to move the base of course operations from Sincelejo to the ICA Research Center at Turipana.

**Conferences and Symposia**

Effective agricultural development programs depend, first of all, upon dynamic, well-informed leadership above the technical level. Those who make and influence national policies, control and allocate credit and resources, manage manufacturing and distribution systems, and provide such facilities as transportation, marketing, processing and storage need unbiased sources of reliable data and estimates of production potentials and requirements.

Moreover, agricultural scientists have a responsibility to communicate effectively with this leadership — to make known what agricultural developments are feasible and what policies and facilitation are required to increase productivity in specific areas and countries.

The developing CIAT program includes facilities and activities whereby national leaders may interact with the scientists of CIAT as well as those of the national agencies. Although CIAT's own facilities are not yet available, a series of conferences, symposia and workshops is already underway.

CIAT expects to incorporate into its conferences and symposia program a concern for sharply focused objectives and appropriate methods of communication, as well as effective procedures for the evaluation of both conference and follow-up activities.

In connection with the release of two new high-yielding rice varieties, CICA 4 and IR22, CIAT planned and sponsored a Seminar on Rice Policies in Latin America, in Cali, October 10-14. Nearly 200 producers, reseachers and policy-makers from 23 countries learned about rice varieties and discussed the probable consequences of their production on the agricultural and related sectors of the Latin American economy. (For more details see Rice.)

A related seminar on "Horizontal Resistance to the Blast Disease of Rice" was held in Cali, October 8-12 (see Rice).

Included in the activities of the conferences and symposia program are cooperative efforts with other Latin American research and training institutions and organizations.

The IV Andean Zone Maize Conference was held in Palmira in November, organized and hosted by ICA and CIAT (see Maize).

Support was also provided in the preparation and distribution of publications for the Third Latin American Meeting on Animal Production, which took place in Bogota, April 26-30. This meeting was sponsored by the Latin American Association for Animal Production, whose vice president is a member of the CIAT animal science staff.

**Social research, field demonstrations and evaluation**

This unit was activated in 1971 with the appointment of a research associate who is responsible for coordinating the communication and economic instruction in all CIAT training programs.

A large part of crop production specialist training through the year has been directed by this coordinator. Students received nearly 50 hours of classroom instruction in economics, focusing on administration of agricultural business enterprises, with emphasis on use of accounting procedures and analysis of production costs and cost-benefit relationships.

A theoretical background in strategies for change and factors for development, perception and behavioral change and inter-personal communication served as the basis in the same training program for a pioneering exercise in practical in-field experience with small farmers in the Cauca Valley (see Training, Crop Production Specialist Training Project, page 108).

In addition to work in the training programs, this unit works with the CIAT economists on socio-economic studies and with other members of the staff on evaluation of certain CIAT activities.

Currently underway is a longitudinal study of the Seminar on Rice Policies in Latin America. Preliminary results indicate that the major immediate impact of this seminar lay in the clarification of the agronomic characteristics of the new high-yielding rice verieties, a strengthening of favorable attitudes toward the adoption of the new rice varieties, and an increasing awareness of the possible effects of existing or modified rice production policies and programs on producers and consumers.

Plans are developing to study the diffusion of the new rice varieties, particularly among small farmers, in Colombia and other countries. By 1973, a longitudinal study of CIAT's training program will be launched.

**Rapport with small farmers is essential to the successful transfer of technology and socio-economic knowledge.**

INFORMATION SERVICES

Activities of Information Services include helping plan, write, edit, translate, prepare copy, incorporate graphic aids and photographs, and print and distribute all of CIAT's publications. In 1971, CIAT Technical Bulletin Nº 1, "The Feasibility of Introducing Opaque-2 Maize for Human Consumption in Colombia", and the first two issues of the bi-monthly newsletter "Noti-CIAT", which is directed toward agricultural development issues of interest to the general public, were produced and distributed to more than 116 countries throughout the world. Both of these publications appeared in English and Spanish editions.

The English version of the 1970 Annual Report was produced for distribution in early 1972, and at the end of the year the Spanish version was in press.

Support of CIAT programs provided by this unit included printing of all documents and materials for the conferences as well as more than 200 documents as training materials.

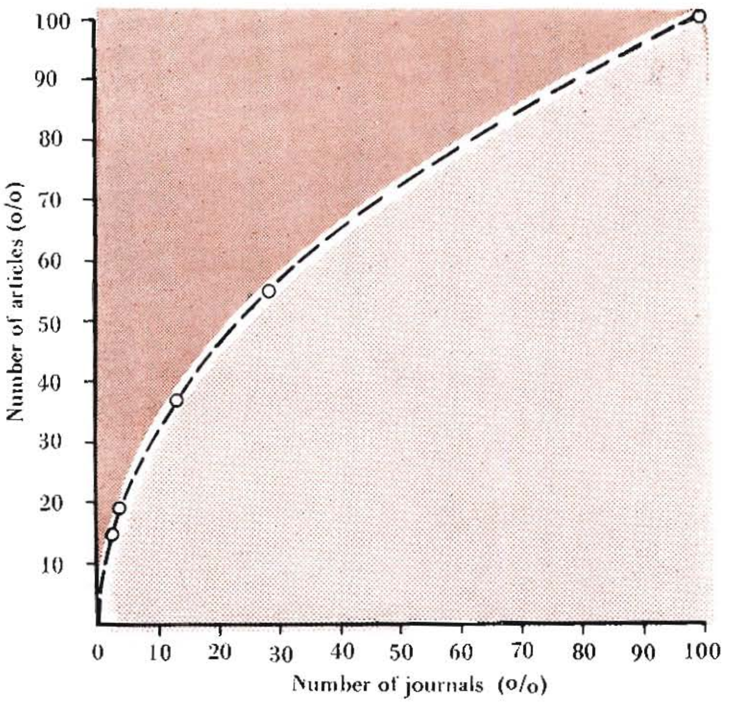



FIGURE 1

## LIBRARY

The present collection of the CIAT Library includes 5,433 titles catalogued, 511 journal subscriptions, and 250 journals received as gifts or through library exchange.

Preliminary talks were held with the International Development Research Centre of Canada for establishing a Cassava Document Analysis Center at CIAT's library. This Center will attempt to collect all the available world cassava literature and publish a comprehensive annotated bibliography on this crop. Supplements will then be issued periodically.

A preliminary analysis of the cassava literature, performed on a sample of 162 articles published in the last four years and obtained from a search at the National Agricultural Library, Beltsville, Maryland, showed a wide scatter of articles. Figure 1 illustrates the results of that analysis.

Cassava literature is published in a wide diversity of journals. As can be seen from the curve, covering 55 percent of the articles would require subcription to 28 percent of the journals, while the remaining 45 percent of the articles would require a 72 percent increase in journal subscriptions.

This and other considerations argue for a more specialized document-by-document approach to cassava literature rather than the traditional library approach which implies subscription to many marginal publications. A document-by-document approach has the added advantage of providing an in-depth analysis of each document.

In a meeting at Rome in November, CIAT was invited to become the regional representative for tropical Latin America in the implementation of a world-wide agricultural information system, AGRIS, sponsored by the Food and Agriculture Organization of the United Nations. The first level of operations to be implemented in AGRIS will be the identification of sources and their compilation into a monthly "current awareness"-type of bulletin.

In connection with this meeting, the librarian traveled to several European institutions considered to be leaders in cassava research, to establish personal contacts and obtain copies of their collections. These institutions included the Tropical Products Institute, London, England; the Royal Tropical Institute, Amsterdam, the Netherlands; the Institute for Tropical Agricultural Research (Institute pour le Recherche Agronomique Tropicale), Nogent-sur-Marne, France, as well the universities of Bonn and Hohenheim, Germany.

In October, Mr. Thomas Bloch, librarian at CIAT for the past two years, completed his two-year contract and began work at the Central American Institute of Business Administration (Instituto Centroamericano de Administración de Empresas, INCAE) in Managua, Nicaragua.

PRICE WATERHOUSE & CO.

APARTADO AEREO 180
CALI - COLOMBIA

April 11, 1972

To the Board of Trustees of

Centro Internacional de Agricultura
Tropical (CIAT)

We have examined the balance sheet of Centro Internacional de Agricultura Tropical (CIAT) as of December 31, 1971 and the related statements of income and expenses and of changes in fund balances for the year. Our examination was made in accordance with generally accepted auditing standards and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances.

Expenses of 1971 and accounts payable as of December 31, 1971 are overstated by $155,783 as a result of including therein commitments for future expenditures in respect of purchases of equipment ($90,120) and expenses ($65,663).

In our opinion, except for the matter referred to in the preceding paragraph, the accompanying financial statements examined by us present fairly the financial position of Centro Internacional de Agricultura Tropical (CIAT) at December 31, 1971 and the results of its operations for the year, in conformity with generally accepted accounting principles.

Price Waterhouse & Co.

## CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL (CIAT)

### BALANCE SHEET

### DECEMBER 31, 1971

(Expressed in U.S. dollars — Note 1)

### ASSETS (Note 2)

| | | |
|---|---|---|
| Cash and banks | | 399,406 |
| Demand deposits | | 50,397 |
| Funds on deposit with, or allocated by, The Rockefeller Foundation, New York (for purchases) | | 129,330 |
| Receivable from Agency for International Development, Washington, D.C. | | 341,493 |
| Advances to employees | | 17,600 |
| Advances to contractors and others | | 237,924 |
| Miscellaneous accounts receivable | | 107,699 |
| Property and equipment (Note 3): | | |
| Land | 4,196 | |
| Farm equipment | 295,030 | |
| Laboratory equipment | 254,781 | |
| Furniture, fixtures and office equipment | 235,511 | |
| Vehicles | 256,783 | |
| Construction in progress | 1,276,482 | 2,322,783 |
| Other assets: | | |
| Experimental livestock | 51,129 | |
| Books and periodicals | 63,992 | |
| Stores | 7,097 | 122,218 |
| Total assets | | 3,728,850 |

### LIABILITIES AND FUND BALANCES

| | |
|---|---|
| Liabilities: | |
| Accounts payable | 378,015 |
| Accrued employees' benefits | 44,688 |
| | 422,703 |
| Deferred income — advance from Interamerican Development Bank, Washington, D.C. | 25,000 |
| Fund balances (accompanying statement): | |
| Capital asset fund | 3,141,182 |
| Operating fund | 139,965 |
| | 3,281,147 |
| Total liabilities and fund balances | 3,728,850 |

**CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL (CIAT)**

**STATEMENT OF INCOME AND EXPENSES**

**FOR THE YEAR ENDED DECEMBER 31, 1971**

(Expressed in U.S. dollars — Note 1)

| | |
|---|---|
| Income:— | |
| Operating grants: | |
| Agency for International Development, Washington, D.C. | 697,006 |
| The Ford Foundation, New York | 680,000 |
| The Rockefeller Foundation, New York | 680,000 |
| The W. K. Kellogg Foundation, Battle Creek | 216,171 |
| International Development Research Centre, Ottawa | 212,625 |
| The Government of the Netherlands, The Hague | 125,000 |
| Interamerican Development Bank, Washington, D.C. | 65,116 |
| | 2,675,918 |
| Sale of farm produce and miscellaneous income | 18,454 |
| | 2,694,372 |
| Core expenses:— | |
| Animal sciences | 491,130 |
| Plant sciences | 551,778 |
| Training and communications | 299,675 |
| Agricultural economics | 77,098 |
| Agricultural engineering and station operations | 206,887 |
| Motor pool | 35,707 |
| Library | 88,480 |
| Biometrics | 1,623 |
| Administration | 229,780 |
| General expenses | 285,356 |
| Purchases of equipment | 90,120 |
| | 2,357,634 |
| Non - core expenses:— | |
| Crop production | 87,824 |
| Conferences and symposia | 40,601 |
| | 2,486,059 |
| Excess of income over expenses | 208,313 |

**CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL (CIAT)**

**STATEMENT OF CHANGES IN FUND BALANCES**

**FOR THE YEAR ENDED DECEMBER 31, 1971**

(Expressed in U.S. dollars — Note 1)

| | Operating fund | Capital asset fund |
|---|---|---|
| Fund balances, December 31, 1970 | ( 68,348) | 2,828,883 |
| Capital grant from The Rockefeller Foundation, New York | | 244 434 |
| Land transferred to Instituto Colombiano Agropecuario | | ( 3,206) |
| Revenue of the capital asset fund in 1971 | | 71,071 |
| Excess of income over expenses in 1971 (accompanying statement) | 208,313 | |
| Fund balances, December 31, 1971 | 139,965 | 3,141,182 |

## CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL (CIAT)

## NOTES TO FINANCIAL STATEMENTS

## DECEMBER 31, 1971

(Expressed in U.S. dollars)

**NOTE 1:**

All foreign exchange transactions are controlled by the Colombian government and, accordingly, all foreign exchange received in Colombia must be sold through official channels. The following exchange rates were used to translate Colombian pesos (P) to U.S. dollars ($):

| | P/$1 | |
|---|---|---|
| Peso balances included in cash and banks, deposits, advances, accounts receivable, other assets and liabilities | 20.78 | Approximate year-end exchange rate |
| Peso disbursements for property and equipment and expenses | 19.92 | Average monthly rate of exchange applicable to sales of dollars |
| Peso income | 19.62 | Average monthly rate of exchange applicable to sales of dollars |

**NOTE 2:**

CIAT operates under an agreement signed with the Colombian government, the most important stipulations of which are as follows:

1. The agreement is for ten years but may be extended if so desired by the parties thereto.
2. CIAT is of a permanent nature and termination of the agreement would not imply cessation of CIAT's existence.
3. If CIAT ceases to exist, all of its assets will be transferred to a Colombian educational or other institution considered appropriate by the parties to the agreement.
4. CIAT is exempt from all taxes.
5. CIAT is permitted to import, free of customs duties and other taxes, all the equipment and materials required for its programs.
6. The government provides land for CIAT's purposes under a rental contract for ten years, at a nominal rent. This contract may be extended by mutual agreement.

**NOTE 3:**

In conformity with generally accepted accounting principles applicable to nonprofit organizations, CIAT does not record depreciation of its property and equipment.