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International Benchmark Sites Network for Agrotechnology Transfer

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PROJECT SUMMARY SHEET

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EXECUTIVE SUMMARY

The International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT) Project is designed to ensure that developing countries keep pace with the rising expectations of their people by sharing in the benefits of the Information Age. The IBSNAT Project employs systems analysis and simulation as a means to transfer agrotechnology for agricultural development. Its aim is to enable developing nations to integrate new crops, products, and practices into existing farming systems to increase production and efficiency, and reduce the drudgery of farm work without disrupting the system. However, when a new crop, product, or practice is introduced, the traditional ways of farming are often altered or displaced, resulting in harmful disequilibrium which causes more failures than successes. The few successes that occur do so more by accident than by design or intent.

The central concept of "systems-based agrotechnology transfer" is that the whole system must be understood in order to evaluate the net impact of an introduced innovation. This approach brings together existing knowledge of the farming system; identifies the critical components, processes, and interactions; and seeks to identify the bottlenecks to improve performance.

The purpose of the IBSNAT Project is to accelerate the flow and increase the success rate of agrotechnology transfer from research centers to farmers' fields. In order to achieve this purpose the project, since its inception three years ago, has accomplished the following:

1. Identified ten major food crops for use in model development and simulation. The IBSNAT crops include four cereals of maize, rice, sorghum, and wheat; three grain legumes of peanuts, *Phaseolus vulgaris* beans, and soybeans; and three root crops of potatoes, cassava, and aroids.
2. Selected the crop model CERES for wheat and maize, and SOYGRO for soybeans to simulate growth, development, and yield. The CERES models have been subjected to global testing and were found to predict crop performance with reasonable accuracy. The soybean model is operational and ready for global testing, and the other seven models are in various stages of development.
3. Produced a manual describing the experimental design and data collection procedures to be used by IBSNAT collaborators.
4. Formed a prototype network of thirty benchmark research sites in sixteen developing countries to collect the minimum data set with which to validate crop models.
5. Created the IBSNAT Data Base Management System to store and analyze the minimum data set collected by the network.
6. Designed model inputs to be identical to the Data Base Management System's output, enabling all IBSNAT crop models access to the data from a single data base.
7. Modified model programs for use with microcomputers so that IBSNAT's crop models are accessible to all collaborators.
8. Mobilized an international group of systems analysts and modelers to work on IBSNAT Project objectives.
9. Developed instructional capabilities to conduct training workshops on system analysis and crop modeling for agrotechnology transfer for developing country researchers.
10. Publicized IBSNAT Project principles, concepts, and progress through brochures, technical reports, conference proceedings, and newsletters.

These accomplishments are designed to serve as the seeds which will grow into national capabilities that rapidly assess the suitability of new crops, products, and management practices at any location, for any season, and for a wide range of user options.

THE IBSNAT PROJECT GOALS AND OBJECTIVES

Project Rationale: Agrotechnology Transfer Through Systems Analysis and Simulation

There is an uncertainty as to whether today's agricultural production methods are adequate to meet the food, fiber, and fuel requirements of populations that are growing in size, hope, and aspirations. Information technology's recent advances offer the hope that costly, time-consuming, site-specific trial and error research can be replaced by systems analysis and simulation techniques, thus answering many more agricultural development questions faster, at markedly lower cost, and in more relevant ways. It is a truism of the "Information Age" that those nations which have access to information and the capability to utilize knowledge, also have the best chance of controlling their destinies. The nations knowing this are already in the race to produce the first Fifth Generation Computer. Because the developing nations are largely spectators in this race, there is a distinct danger that the Information Age will widen the technological gap between rich and poor nations, making developing countries even more dependent on others for food and security.

One dilemma of less-developed countries (LDC) is that the lifesaving benefits of medical technology have not been matched by food production increases of agricultural technology. This is because the success of agricultural technology, unlike medical technology which is generally user and environment neutral, depends on the cultural and resource characteristics of the user, and on the environment to which it is transferred. For example, the technology to immunize populations against measles applies to people everywhere, regardless of their social or economic standing. In contrast, the high performance cultivar of a food crop, developed in an agricultural research center, cannot be transferred to all farmers around the world. The plant that emerges from the seed is extremely sensitive to the biophysical environment in which it is planted. Even if environmental conditions were ideal, the farmer may not have the resources to exploit the plant's genetic potential.

Food production in the past has tried to keep pace with population growth through the introduction of technology by trial and error to various locations in the world. Technology transfer by trial and error has had a low success rate, and is too slow and costly to meet today's challenge. A better approach is to transfer agricultural technologies among analogous environments. Transfer by analogy minimizes the number of mismatches between the requirements of the technology, and the characteristics of the user and the environment. Climate analogues are still used to select suitable sites for new crops and farming prescriptions. The Benchmark Soils Project (USAID Contract No. ta-C-1108), predecessor of the IBSNAT Project, demonstrated that a combination of soil and climate analogues can be used to successfully transfer agricultural technology in the tropics.

Technology transfer by analogy has one limitation, however: it provides no insight as to how technology might be transferred to nonanalogous locations. In order to transfer agricultural technology to nonanalogous environments, one first must understand, and then predict and control the biophysical processes. The ability to analyze large amounts of data rapidly and inexpensively, means that we can now simulate events and outcomes that only a few years ago were never thought possible. Agricultural technology transfer through systems analysis and simulation enables the transferrer to assess the suitability and appropriateness of the transferred technology. This means more agrotechnology transfers will be successful. IBSNAT is based on the premise that the war on hunger can be won, not only by creating more technologies, but also by transferring new and existing technologies to locations where they will be successfully used.

Each disease conquered by medical technology must be matched by agricultural technology in order for those living to nourish, clothe, and shelter themselves. Without the successful transfer of agrotechnology, malnutrition and death will spread and increase in spite of medical victories.

IBSNAT Project's primary aim is to develop a method for transferring agroproduction technology, which

combines the elements of transferal by analogy with system analysis and simulation techniques, that will:

- accelerate the diffusion of agrotechnology from its site of origin to new locations;
- maximize the rates of success, while minimizing the chances of failure for transferring agricultural technology in the tropics and subtropics; and
- simulate the effects of the long-term agricultural practices on the environment.

The purpose of this report is to inform readers of the progress that IBSNAT Project collaborators have made to attain the stated objectives.

Statement of Goal

The goal of the IBSNAT Project is:

To accelerate the flow of agrotechnology transfer to and between developing countries on a cost-effective and scientific basis to improve the understanding of cropping systems, provide decision makers with the means to predict crop yields using crop simulation models, and use crop models to develop management strategies at all levels.

Project Objectives

The primary thrust of the IBSNAT Project is to create a prototype network of national, regional, and international institutions that will enable a ready exchange of agricultural technology among tropical countries. The objectives of the project are:

1) to accelerate the flow of agrotechnology on a scientific basis from its site of origin to recipient sites with a well-characterized agroenvironment; and
2) to increase the success rate of technology transfer from agricultural research centers to farmers' fields.

The IBSNAT Project aims to achieve its objectives by the following activities:

A) Establishing a network of collaborating national, regional, and international agricultural research centers to serve as sources and recipients of agrotechnology;
B) Identifying the soil, crop, weather, and management data needed to successfully transfer agrotechnology;
C) Using systems analyses, and soil, crop, and weather models to predict the performance of crops and management systems;
D) Testing and validating soil, crop, weather, and management simulation models in a network of experimental sites; and
E) Training collaborators to use systems analyses, and soil, crop, and weather simulation, and management models for agrotechnology transfer.

Project Approach

The IBSNAT Project operates as a prototype network of collaborating national, regional, and international research centers with experiment stations in dominant agroecological zones, and with representative kinds of soils of the tropics and subtropics.

At the March 1983 international IBSNAT symposium held in India, 59 collaborating IBSNAT scientists gathered and chose ten crops to study. Cereals, grain legumes, and root crops were selected for model development or modifications, and for calibration and testing. The scientists agreed on experimental procedures and management practices designed to collect standardized minimum data sets. The IBSNAT Project at the University of Hawaii headquarters, serves both as a primary reference source and as a centralized storage of data sets for agrotechnological information for IBSNAT's local scientists working in the different agroecological zones around the world. The cumulative data sets are stored and managed from one global data bank, and are accessible to all collaborators. Minimum data sets of crop performance over a wide range of agroenvironments are necessary to develop and validate crop models for global use.

The minimum data sets are returned to IBSNAT for centralized storage and retrieval in the Data Base Management System (DBMS). From this computerized information bank, all accumulated data sets are available to IBSNAT collaborating network of users and modelers. Aside from specific data retrieval by other scientists for their own purpose, the data sets from tropical and subtropical countries are utilized for training collaborating local researchers to design crop models specific for their own country.

The crop models allow predictions of crop potential and performance at locations where the crop has not yet been grown. Although models cannot substitute for field experiments, they offer two advantages: 1) the possibility of considering alternative crops in various combinations of environmental factors for experimentation; and 2) the savings of money and time on otherwise exhaustive field experiments carried out over several years, and at several locations with varying weather and soil properties. While considering their specific local conditions, beneficiary developing country's scientists and planners can assess the suitability of

their lands for the crop in question, and estimate the land productivity by designing soil and crop management techniques to obtain optimum agricultural production.

When crop models for a worldwide network of experimental sites have been verified and validated, collaborators can facilitate dissemination and utilization of IBSNAT Project results by training others in the use of IBSNAT principles and concepts for crop modeling. Collaborative networking is a new, innovative, and cost-saving way to do research.

The IBSNAT collaborators anticipate that a prototype network of research centers, sharing common information through the Data Base Management System, will be fully operational by 1989. Scientists at the Agricultural Research Service (ARS) in Temple, Texas, along with IBSNAT collaborators, envisage by 1988, the development of a general agricultural systems model, which would be capable of simulating the effects of soil, weather, crop, and management parameters on the biological and economic performances of cropping systems.

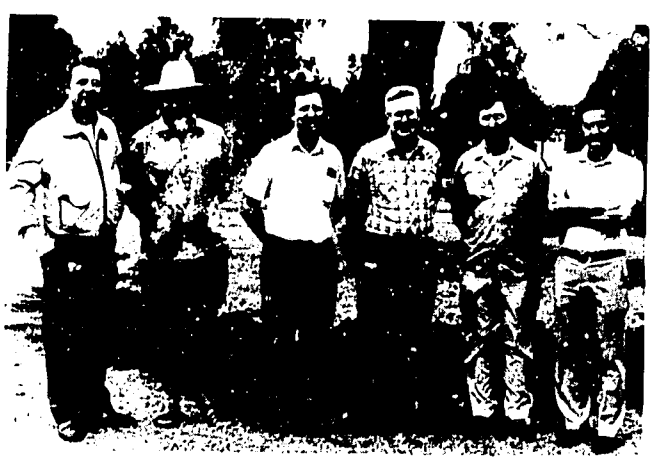
Project Management

The United States Agency for International Development (USAID) contract is a direct agreement with the University of Hawaii to provide organization, leadership, and support for IBSNAT activities, including the subcontracts with the University of Puerto Rico at Mayaguez; the Grassland, Soil and Water Research Laboratory at Temple, Texas (ARS); the Institut National de la Recherche Agronomique (INRA) in Toulouse, France; and the University of Florida. Through USAID funding, formal cooperative activities have also involved the Soil Management Support Services (SMSS), the Soil Conservation Service (SCS), National Soil Survey Laboratory (NSSL), the International Fertilizer Development Corporation (IFDC), and Michigan State University. The IBSNAT Project has initiated informal agreements with the Commonwealth Scientific and Industrial Research Organization (CSIRO), national collaborators in Australia, the Department of Scientific and Industrial Research (DSIR) scientists in New Zealand, and with nine developing countries. Approximately thirty more countries are expected to participate with IBSNAT in the near future.

AID's contracting institution, the University of Hawaii, does not exert direct control over the worldwide network of collaborators. Rather, IBSNAT collaborators rely on the leadership of the dedicated scientists, and on the prospect of mutual benefits for all participants. In order to exercise management and quality control, persuasive presentations and support activities are provided by IBSNAT, which assure the essential cooperation and coordination necessary for maintaining the projected schedule and achieving the IBSNAT Project's objectives by 1991. The IBSNAT Project's incentive for motivation that encourages participation includes activities such as special purpose working groups, field visitations, collaborative progress reviews, instructional workshops, and informative symposia.

Efforts to obtain reasonable "management control" at IBSNAT headquarters are the establishment of: 1) two advisory committees; and 2) a management committee to counsel the Principal Investigator.

The Technical Advisory Committee (TAC) was es-



The Technical Advisory Committee (TAC) is composed of five internationally recognized scientists (from left to right): Juan A. Comerma, Henry A. Nix, J. Barry Dent, L. Anthony Hunt, and Joe T. Ritchie. Goro Uehara stands with the TAC members; Ritchie is chairperson of this committee.

The Collaborators' Advisory Panel (CAP) met at the 1985 IBSNAT Project Review. They are (from left to right): Ramon V. Valmayor, Goro Uehara (IBSNAT Principal Investigator), Peter Goldsworthy, and Rodrigo Tarte. The fourth CAP member, Gunawan Satari, is not present in the photo.

tablished in 1984 and is composed of five internationally recognized scientists in disciplines that have relevant implications to IBSNAT activities. The TAC members provide advice on technical matters related to systems analysis, and crop models and simulation. Current members of TAC include J. A. Comerma of Fondo Nacional de Investigaciones Agropecuarias (FONAIAP), Venezuela; J. B. Dent of Lincoln College, New Zealand; L. A. Hunt of the University of Guelph, Canada; H. A. Nix of the Commonwealth Scientific and Industrial Research Organization, Australia; and J. T. Ritchie of Michigan State University, USA. The TAC chairperson is Ritchie.

The Collaborators' Advisory Panel (CAP) was established in 1985, and has four members from national, regional, and international agricultural organizations. Members of CAP are P. Goldsworthy of the International Center for Agricultural Research in the Dry Areas (ICARDA), Syria; G. Satari of the Agency for Agricultural Research and Development (AARD), Indonesia; R. Tarte of Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), Costa Rica; and R. Valmayor of the Philippine Council for Agriculture and Resources Research and Development (PCARRD), Philippines. During the IBSNAT Project Review, CAP members met for the first time to provide suggestions and recommendations on strategies to utilize IBSNAT Project concepts for agricultural development and planning.

The Executive Management Committee (EMC) was established in 1984 and is composed of F. H. Beinroth, University of Puerto Rico at Mayaguez; H. Eswaran, Soil Management Support Services and Soil Conservation Service (SMSS/SCS); G. Y. Tsuji and G. Uehara, University of Hawaii; and T. S. Gill of the Agency for International Development, Bureau of Science and Technology, Office of Agriculture, Renewable Natural Resources (AID/S&T/AGR/RNR). The EMC is responsible to the Principal Investigator regarding all matters related to the operational management and implementation of activities to achieve IBSNAT Project objectives.

ACCOMPLISHMENTS TO DATE

- Network Establishment
  - Collaboration with Soil Management Support Services
  - Network of Collaborators
    - Model Development
    - Model Testing
- Data Base Generation for Agrotechnology Transfer
  - Concept of Minimum Data Sets
  - Identifying the Minimum Data Sets
  - Minimum Data Sets Guidelines
- IBSNAT's Shared Data Base Management System
  - Why IBSNAT Uses Microcomputers
  - A Scenario on How the DBMS is Designed to Work
  - Data Base Management System Design Stages
  - Data Base Management System's Current Stage of Development
- IBSNAT Crop Models
  - Current Status of Crop Models (Table 5)
  - Cereals: Wheat, Rice, and Sorghum Models
    - Progress on the Continuing Validation of the CERES Maize Model
  - Grain Legumes: Peanuts and Beans Models
    - SOYGRO: Soybean Crop Model for Technology Transfer
  - Root Crops: Potatoes, Cassava, and Aroids (taro) Models
- Data Generation for Model Calibration and Testing
  - Progress Reports from IBSNAT Collaborators
  - Collaborators' Status of Field Experiment

Progress of planned activities associated with each output to achieve IBSNAT Project's stated goals and objectives is reported in this section. Requirements of a global prototype network are described under the output on Network Establishment. Subsequent paragraphs discuss the collaborators' agreement on the Minimum Data Set to test crop models, and for conducting research through systems analysis and simulation. Next, is a description of IBSNAT's progress in the development of the Data Base Management System; its structural design; its capabilities for storage and retrieval of crop, soil, weather, and management data; and its interactive role to link the minimum data set to crop models. Model verification, calibration, and validation procedures for maize and soybeans are reported; and progress of model development for the other eight crops are presented in the fourth part. The IBSNAT collaborators' efforts in planting experiments to calibrate and test several crop models are presented in the last part of this section, with reports from Venezuela, Hawaii, Zambia, Panamá, Burundi, Guam, Thailand, and Syria. The status of IBSNAT field experiments which are planned or in progress are shown as the Crop Planting Schedules received from collaborating scientists (see Appendix A).

Network Establishment

The IBSNAT Project has established a global prototype network of collaborating institutions and organizations for agrotechnology transfer. The network involves collaborators' participation in site characterization; data generation; data base management systems; model development, calibration, and testing; and training in the use of systems simulation and modeling.

The IBSNAT network establishment was initiated through communication with those collaborators who share common interests in extending the concept of soil-based agrotechnology transfer to one which utilizes systems simulation. The bond or linkage among collaborators in the network is the desire to standardize data sets and data collection procedures. The consensus of IBSNAT collaborators is to collect a series of minimum data sets for four cereals, three grain legumes, and three root crops, for the express purposes of testing existing crop models, and for developing other crop models that are nonexistent or partially developed. It is anticipated that each collaborator who generates data sets will eventually be able to use simulation software to calibrate and validate the use of crop models in their respective countries or region.

The following paragraphs contain brief descriptions of collaborative activities established for the IBSNAT prototype network. Further elaboration and description of these activities are presented in subsequent sections.

Network of Benchmark Sites

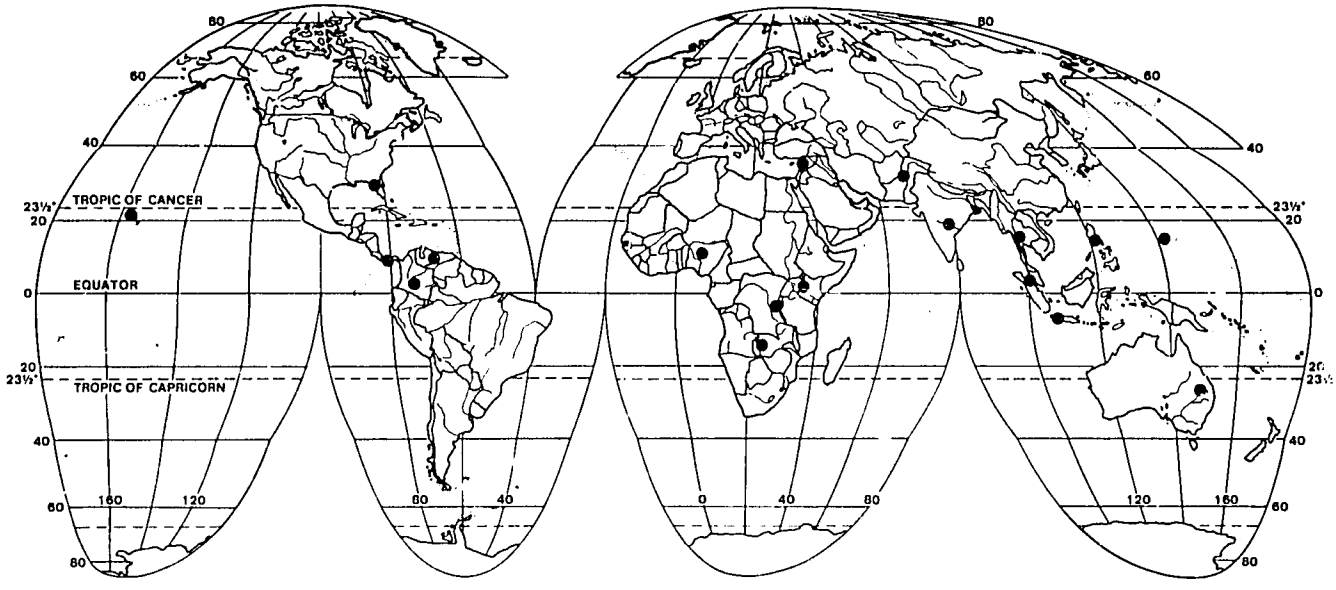


Figure 1. The IBSNAT experimental sites cover a wide range of soils and climates.

Collaboration on Site Characterization

Collaboration on site characterization has been accomplished by a mutual agreement with the Soil Management Support Services, an AID program implemented by the Soil Conservation Service of the United States Department of Agriculture (USDA). Successful transfer of agrotechnology depends on the crop models and also on accurate knowledge of ecological characteristics of the recipient sites.

In response to requests initiated by potential collaborating countries through the local USAID Mission, the SMSS Program of the USDA/SCS sent soil scientists to various countries (Table 1 and Figure 1).

Soils at designated sites of the IBSNAT prototype network have been characterized, analyzed, and classified through collaboration with SMSS and IBSNAT. The soils were classified according to *Soil Taxonomy*, the USDA Agricultural Handbook No. 436 which is the reference for a basic system of soil classification.

Table 1. IBSNAT network of benchmark sites where soil has been sampled by USDA/SCS scientists.

Country	*Organization*
Burundi	University of Burundi
Fiji	MPI
Guam	University of Guam
USA Hawaii	University of Hawaii
India	ICRISAT
Indonesia	AARD/CSR
Pakistan	Soil Survey of Pakistan
Panamá	IDIAP
Philippines	PCARRD
Syria	ACSAD
Thailand	Land Development Department
Venezuela	FONAIAP
Zambia	University of Zambia

Collaboration on Modeling and Data Base Management

Collaborating scientists representing many organizations (Table 2) have been involved in programming software for computer simulation of crop development and growth. Through mutual agreements and subcon-

Table 2. Development of IBSNAT model programs by collaborating institutions and agencies.

Organizations	*Model Programs*
USDA/ARS	Cereal Model
	Erosion-Productivity Impact Calculator (EPIC) Model
CIAT	Cassava Model
	Beans Model
Cornell University/CIP	Potatoes Model
CSIRO	Root Crop Models
FAO	Crop management data base
	Soil management data base
ICRISAT	Sorghum Model
IFDC	Soil Nitrogen Model
INRA	Data base management
NOAA/Utah State	Weather data base
	Weather Model
SMSS	Soil data base
University of Florida	Grain Legume Models

Network of Collaborators

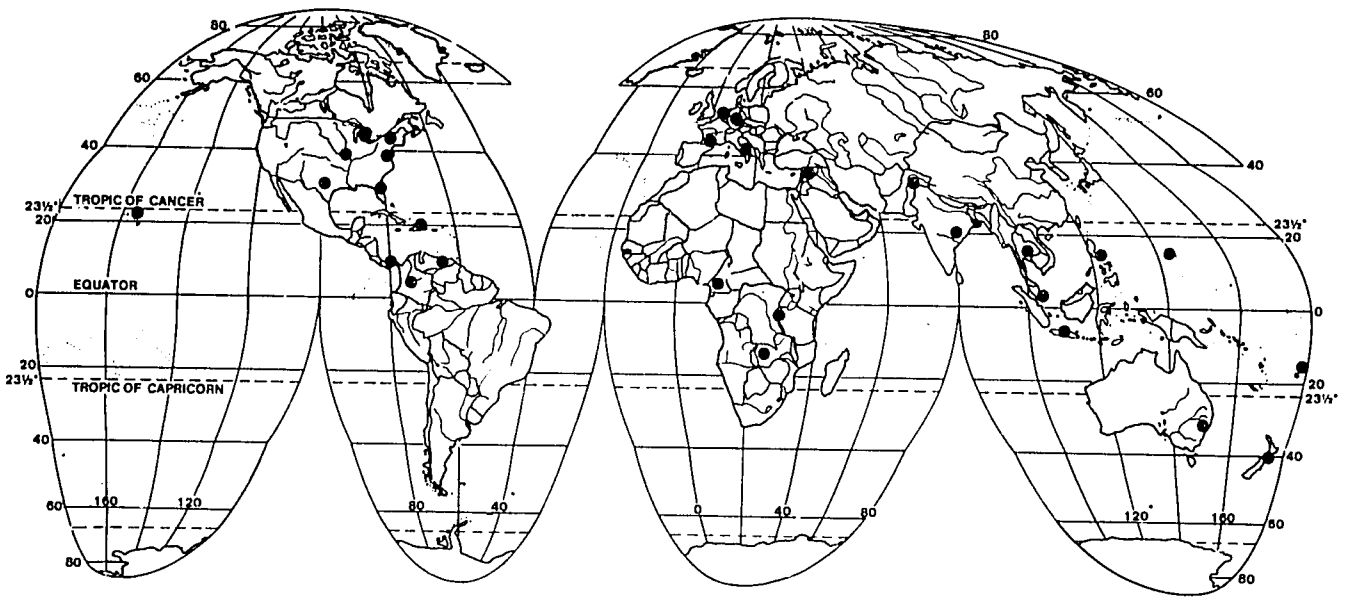


Figure 2. The IBSNAT network of collaborators represent many countries around the world.

tracts with the Research Corporation of the University of Hawaii (RCUH), the collaborators have agreed to provide support to IBSNAT in the form of computer software, data analyses, and consultation services.

The University of Hawaii is responsible for the development and implementation of the Data Base Management System (DBMS). The DBMS now has compatible input and output formats that allow interactions with the various crop models.

The IBSNAT Project, with headquarters on the University of Hawaii campus, is coordinating and facilitating the development to strengthen the linkages among collaborators, and with groups involved in developing and testing crop simulation models for agrotechnology transfer.

Collaboration on Data Generation and Model Testing of a User Network

Communication linkages have been established with several countries for the purpose of exploring their common interests in collaborating with and participating in the IBSNAT prototype network (Figure 2). Memorandums of Agreement have been or are being prepared for transmittal to agencies or organizations that have expressed interest in participating (Table 3).

In principle, IBSNAT collaborators agree to provide the necessary resources for recording and monitoring the minimum data sets (MDS) used in model testing and development. Minimum data sets are collected according to the *Experimental Design and Data Collection Procedures for IBSNAT* (IBSNAT Technical Report 1). The MDS are submitted to Hawaii headquarters for entry into the IBSNAT data base management system. Collaborators employing the principles and concepts of IBSNAT are shown in Table 3.

Data Base Generation for Agrotechnology Transfer

Concept of Minimum Data Sets

The concept of minimum data sets in agronomic research is a relatively new idea which arises directly from adoption of the systems-based research strategy. A data base containing a balanced set of essential information on the soil-plant-atmosphere continuum is necessary for developing crop models.

The lack of adequate data bases is the major limitation to crop model development. Agronomists often collect more data than are actually needed to accomplish research objectives, however the types required for modeling work, such as weather and crop phenology data, are usually omitted. Moreover, the experiments cover only a narrow range of environments and cannot provide sufficient data to define the major radiation, temperature, water, and nutrient regimes that regulate crop response.

Considering the fact that field experimentations cost time and money, it is neither necessary nor practical to develop a crop model in more detail than that required for useful and accurate predictions in its application mode. The emphasis of agronomic research based on systems analysis should therefore be concerned with

Table 3. IBSNAT Project network of regional, national, and international collaborators.

Country	*Type of Center*	*Agency*
Australia	National	*CSIRO
Burundi	National	*University of Burundi
	Regional	IRAZ
Cameroon	National	IRA
Colombia	International	CIAT
Costa Rica	Regional	*CATIE
Fiji	Regional	*MPI
France	National	†INRA
Guam	Regional	*University of Guam
India	International	ICRISAT
Indonesia	National	AARD/CSR
Jordan	National	*University of Jordan
Morocco	National	INRA
Pakistan	National	PARC/NARC
Panamá	National	*IDIAP
Philippines	National	PCARRD
Puerto Rico	Commonwealth	†University of Puerto Rico
Syria	Regional	ACSAD
	International	ICARDA
Taiwan	International	*AVRDC
	Regional	*FFTC/ASPAC
Thailand	National	*Land Development Department
	National	*Department of Agriculture
USA, Alabama	International	IFDC
USA, Florida	State	†University of Florida
USA, Hawaii	State	*University of Hawaii
USA, Michigan	State	Michigan State University
USA, Texas	Regional	†USDA/ARS
Venezuela	National	*FONAIAP
Zambia	National	*University of Zambia

*Memorandums of Agreement have been returned to IBSNAT Hawaii headquarters.

†These agencies have subcontracts with IBSNAT Project as of July 1984.

data generation which satisfies the standard minimum that is specified by a model for its successful development, validation, and application. The generated data should contain a balanced set of crop, soil, weather, and management parameters which account for the variability in yield or other measures of crop performance from site to site and year to year.

The collaborators' commitment to collect standard minimum data sets for developing global crop models requires a global research network. With the pooling of data sets into a single data base, it would be possible to develop general crop models that are applicable to any combination of genotypes and environments.

Identifying the MDS

The first IBSNAT symposium on the "Minimum Data Sets for Agrotechnology Transfer," was held in Hyderabad, India, 20–26 March 1983. Fifty-nine scientists from regional, national, and international research centers attended the meeting, which was organized by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), the Soil Management Support Services, and the IBSNAT Project. The symposium's discussions focused on the crops to be researched, the design of experiments for data generation, and the minimum data set to be collected during each experiment.

According to each country's agricultural and economic resource base, the participants recommended that ten crops representing cereals (maize, wheat, sorghum, and rice), grain legumes (*Phaseolus* beans, soybeans, and peanuts), and root crops (potatoes, cassava, and aroids) be targets for model development. Because each of these crops grow in defined biophysical environments, and over a wide range of socioeconomic situations, they offer the project a challenge to develop a methodology for technology transfer. Initially, only the IBSNAT selected crops will be considered; however, other crops may eventually be included depending on the collaborators' priorities, resources, and progress.

The first symposium reached the general consensus that a standard design for IBSNAT's field experiments was not feasible. First of all, research priorities and capabilities among collaborators are too variable; and secondly, the crop models are in various stages of development. For example, aroids models are practically nonexistent, whereas maize and wheat models are near completion. Therefore, it was necessary for the field experiments to be flexible in order to match the stages of crop model development.

It was emphasized at the 1983 IBSNAT symposium that both modelers and field researchers should work cooperatively on designing the experiments, and with no one discipline dominating. Collaborators should aim at upgrading their experiments in ongoing research programs, through additional measurements and observations, to obtain minimum data sets quickly and efficiently. Also, experiments should be conducted over a wide range of agroecological conditions to ensure the development of a comprehensive crop model.

In light of the IBSNAT Project's objectives, two minimum data sets were identified: one for model development and one for testing operational models. The minimum data set for model development includes the same measurements and observations as for model testing, plus additional data on soil fertility, crop phenology, tissue analysis, and leaf area index

For weather data, the daily incoming solar radiation, maximum and minimum air temperature, and precipitation must be measured sufficiently close to the experiment to reflect site conditions.

For soil data, it is mandatory to have standard descriptions, analytical characterization, and classification according to *Soil Taxonomy*, as well as the measurements of nitrogen, phosphorus, and potassium content (NPK); and soil acidity of the surface horizon (0 to 15 cm depth) prior to planting. When fertility is a treatment, the nutrient status of the soil profile should be determined at planting and after harvest. When water is a limiting factor, volumetric moisture content in the profile should be measured at planting and after harvest. Other required soil information relates to tillage operations, such as the depth of tillage, residues incorporated, and, when and how the operation was performed.

For crop data, the dates when major phenological stages occur must be recorded. The key events differ somewhat among the crop groups, but basically are: a) emergence; b) a vegetative stage when the crop is growing rapidly; c) anthesis, the state of full bloom; and d) physiological maturity. At each key phenological event, total shoot dry matter production must be determined. Tissue nutrient concentrations are necessary when fertility is a treatment. In addition, at final harvest, the yield components such as seed weight, seed number, ears, and established plants per unit area are determined.

Management data includes general information about the collaborating institution and researcher, and specific information about the design, plot layout, and treatments. Crop husbandry details for cultivar, planting date, row spacing, seeding rate, and planting depth also need to be reported, along with the record of the kinds and levels of input. Fertilizer, irrigation, inoculants, and agrichemicals must be measured. Pest problems must also be identified, and the resultant crop damage assessed and recorded.

Minimum Data Sets Guidelines

The need for guidelines to implement the agronomic experiments and collection of the minimum data sets was recognized at the first IBSNAT symposium. In January 1984, a small group of IBSNAT experimenters and modelers met at the Grassland, Soil and Water Research Laboratory (USDA/ARS) in Temple, Texas to prepare a draft of the manual. Personnel involved were F. B. Cady, Cornell University; J. A. Comerma, FONAIAP-CENIAP, Venezuela; J. A. Silva, University of Hawaii; P. T. Dyke and C. A. Jones, both of USDA/ARS, Texas.

In August 1984, at the second annual IBSNAT meeting held in Hawaii, collaborators reviewed the draft and took part in a group discussion to reach consensus on experimental design and data collection procedures. The guidelines were revised by C. A. Jones to incorporate the collaborators' recommendations. Most of the revisions dealt with the crops' key phenological stages, and the collection of biomass and yield components.

The *Experimental Design and Data Collection Procedures for IBSNAT* (IBSNAT Technical Report 1) was printed and distributed by the IBSNAT Project in December 1984. A second printing was necessary in March 1985 to meet the requests of IBSNAT collaborators, and to date more than 750 manuals have been distributed.

The manual organizes the data set into standardized forms to facilitate monitoring, collection, recording, and transmittal of the data. Nineteen forms are used to log data, and each type of data is identified by a code for efficient entry into the Data Base Management System (Table 4).

After the first year of field usage, Technical Report 1 will be evaluated for its effectiveness as a user's guide for generating data sets, and will be revised accordingly.

IBSNAT'S Shared Data Base Management System

IBSNAT is in the process of using microcomputers to develop a centralized DBMS that integrates collaborators' experimental data sets with cultivar, soil, and weather information into a standardized and usable form. The resultant integrated centralized data base provides each collaborator with access to a greater amount of data then they now have.

The proposed DBMS system supplies the functional linkage among various IBSNAT collaborators who

Why IBSNAT Uses Microcomputers

The IBSNAT Project aims to develop an efficient and sophisticated, yet user-friendly DBMS for use by collaborators who do not have access to mainframe or minicomputers. This limitation dictates that the system be designed for microcomputers. Using a microcomputer for the DBMS has several features that make it attractive as part of the overall data base management strategy.

- Microcomputers are now sufficiently powerful for IBSNAT's computing requirements.
- Many software packages are available for microcomputers that previously were only available for larger computers.
- A microcomputer DBMS is portable, and IBSNAT can easily distribute the DBMS and data file diskettes to collaborators worldwide.

Table 4. Summary of the data requirements of the IBSNAT Minimum Data Set. The minimum requirements for three types of experiments are indicated with X. Optional data are indicated with O.

		Type of Experiment		
Type of Data	*Form*	*Fertility suboptimal or variable*	*Water suboptimal or variable*	*All other experiments*
Institution information	A	X	X	X
Long-term weather data from nearby weather stations	B	O	O	O
Daily weather data during the experiment	C	X	X	X
General information about the experimental area (field)	D	X	X	X
General information about the experiment	E	X	X	X
Codes and cross-references of experimental factors, levels, and plots	F	X	X	X
Experimental layout	G	X	X	X
General plot information	H	X	X	X
Soil fertility	I			
Preplant surface samples		X	X	X
Postharvest surface samples		X	O	O
Preplant and postharvest subsurface samples		X	O	O
Preplant and postharvest volumetric soil water in profile	J	O	X	O
General tillage information	K	X	X	X
Crop cultivar information	L	X	X	X
General planting information	M	X	X	X
General information on fertilizer, inoculant, and amendment application	N	X	X	X
General information on biocide and hormone application	O	X	X	X
Irrigation information	P	X	X	X
General information on damage to the crop	Q	X	X	X
Data on growth stage and yield components several times during the season	R	X	X	X
Plant nutrient concentrations	S	X	O	O

Source: Jones C. A., ed. 1984. Experimental Design and Data Collection Procedures for IBSNAT. IBSNAT Tech. Rept. 1. Dept. Agron. Soil Sci., College of Trop. Agr., Univ. of Hawaii. p. 20.

contribute experimental data, soil characterization data, simulation models, and statistical analyses expertise. The DBMS provides all IBSNAT collaborators with a common framework for communication, and for building a system that will be most useful in evaluating the potentials and limitations of crops growing in specific soil, climate, and management conditions.

The relational structure of the IBSNAT DBMS permits simplified data changes, avoids information repetition in the data files, relates data files by common keys, and provides fast data retrieval. Microcomputers provide collaborators with an efficient and user-friendly data base management system without requiring access to a mainframe or minicomputer.

From the IBSNAT central data base which includes the minimum data sets, collaborators will be able to compare their field results with other data sets from around the world, and evaluate the computer simulation models for application to their own environmental conditions. The sharing of data allows regional and individual collaborators the use of agrotechnological applications that were not previously possible. When the data base management system becomes fully operational, IBSNAT collaborators will have an efficient and sophisticated data base system that is easy to use, and that can be tailored for their adoption and specific needs.

The DBMS has been designed to amplify the results

of individual experiments in two ways. First of all, by pooling results from similar experiments into one computerized system, the combined data can be analyzed for similarities and statistical relationships between site and crop response characteristics. Secondly, the IBSNAT DBMS simplifies the use of experimental results through its direct access to crop simulation models. The DBMS has been designed to link data sets from collaborators for direct input into crop simulation models. Thus, collaborators can compare model simulation results with their own experimental data to assess the model's usefulness for their agroecological conditions. The models can then be used to explore alternate cultivars, management, or crops for local soil and climate conditions. The crop models are especially helpful in predicting crop performance where detailed and costly experiments cannot be conducted.

A Scenario on How the DBMS is Designed to Work

After a collaborator conducts an experiment in a country, a maize experiment for example, the IBSNAT minimum data set for soil, crop, weather, and management data is entered in the microcomputer using the DBMS software developed and supplied by IBSNAT. When all the data has been entered, a copy of the floppy diskette containing the data is made, and returned to IBSNAT Hawaii headquarters. The Soil Management Support Services pedon number is included so IBSNAT can access the soil pedon and characteristic data, and enter the information in the soil data file. Prior to field data entries, the crop modeling collaborators entered the maize model and its associated crop genetic data into the IBSNAT system.

The centralized IBSNAT DBMS integrates the collaborator's field experiment results with the soil and crop data, and creates the input data files necessary to run IBSNAT crop models. IBSNAT generates a summary analysis, and provides a computer printout of the collaborator's experimental results. The summary analysis printout and the floppy diskettes are returned to the collaborator to use with available crop models.

After several seasons of experiments, when the collaborator is convinced that the model can simulate local situations reasonably well, a more comprehensive analysis of yield results can be conducted using the model for different soil types, planting dates, and irrigation strategies to determine the most promising and least risky combinations for his agroecological conditions.

The important point demonstrated by this example is: the DBMS provides the major mechanism through which the IBSNAT Project links collaborators, crop modelers, agronomists, soil scientists, and computer experts. By providing such a linkage, different collaborators can share both the knowledge and the experiences of common crops and soils.

DBMS Design Stages

Based on the collaborators' inputs, minimum data sets were designed to meet their information needs for both field experiments and computer models. Using the collaborators' data sets and their comments, IBSNAT designed a conceptual model for the DBMS which consolidated the input from all collaborators. The DBMS model has the ability to check for consistency of information and to validate identifiable relationships between the data items. The result is a comprehensive definition of the data base requirements of all collaborators put together into a single, consistent data base description.

An agreement to use a commercially available relational data base software package for developing the IBSNAT DBMS was reached during the first TAC meeting in 1984. IBSNAT needed a data base management system which was portable, affordable, potentially useful to all collaborators, and which would provide fast information retrieval. With this in mind, IBSNAT selected the dBASE III[1]. The advantages of using this relational data base system include the following:

1) Ease of use—it is the easiest system to work with since it is based on simple files consisting of columns and rows.
2) Flexibility—permits "cutting and pasting" of data files.
3) Precision—links established between various files are accurate and logical.
4) Relatability—any data file can be related to other data files by using a common key.
5) Data independence—either the data or the application program may be changed without changing the other.

During the December 1984 systems analysis and crop simulation workshop held in Venezuela, the instructional team of modelers identified a significant potential limitation in using the DBMS with different crop models. Specific difficulties arose due to incompatibility of the different input and output formats of the physical data set and crop models.

In April 1985, a workshop was held to evaluate the finalized IBSNAT DBMS input program, link the minimum data sets to the crop models using the DBMS, and work out the problems and limitations that had been identified at the Venezuela training workshop. The meeting was held at the Grassland, Soil and Water

[1]dBASE III is a trademark of Ashton-Tate, 10150 West Jefferson Blvd., Culver City, CA 90230.

Research Laboratory in Temple, Texas, and the major focus was evaluation of the physical model. This evaluation was essential prior to implementing the data base and writing the application programs. Input error checking routines have been built into the DBMS input programs to ensure valid and correct data entry.

The DBMS modeling workshop allowed IBSNAT to obtain recommendations from collaborators for short- and long-term DBMS planning. The specific recommendations are that the IBSNAT Project will:

A) Work with modelers to develop IBSNAT versions of existing maize, soybean, and wheat models;
B) Work toward standardizing summary output formats for IBSNAT simulation models and summary analyses for each minimum data set; and
C) Provide periodic status reports of the data stored in the IBSNAT DBMS, as well as software available through IBSNAT.

DBMS Current Stage of Development

The DBMS developmental phase began after construction of the relational experiment data files based on the minimum data set forms. The current work encompasses constructing the soil data files, cultivar data files, and crop parameter data files for the collaborators' central data base (Figure 3). Part of the soil data files development will include creating a software information retrieval system to extract necessary data from the existing data base of the USDA Soil Conservation Service.

The soil, cultivar, and crop parameter data files, together with the weather and experiment data files, make up the collaborators' central data base which is the heart of the IBSNAT DBMS. Merging of these five files into the data base structure permits the generation of model-specific data bases that are essential for running the crop models.

A model-specific data base can be generated from the collaborators' central data base for each crop model (Figure 3). This is accomplished by using a DBMS data retrieval system. The model-specific data bases are necessary because each crop model has different characteristics and needs, and requires only a portion of the collaborators' central data base. The model-specific data bases increase the speed of data retrieval for simulation.

In order to safeguard data consistency between the collaborators' central data base and model-specific data bases, no editing is allowed in the collaborators' central and the model-specific data bases that are stored at IBSNAT Hawaii headquarters. This ensures that information stored in the central data base will match model-specific data bases.

In the conceptual structure of the collaborator's model-specific data base, each individual collaborator may request specific data sets which they can edit for model testing. Two main software packages will be included with the data sets. One will run the collaborator's data base, and the other package will provide individual simulation programs for each specific crop model.

Requests for data sets by collaborators can include all or part of the data sets stored in the centralized IBSNAT DBMS. Standard output includes data summaries, data analysis of each experiment, and a printed copy of the collaborator's experimental results; these can also be requested.

The data sets that are given to the collaborators will become part of their individual data bases. From the individual data base, separate model-specific data bases can be generated, and they provide the data for collaborators to run particular crop simulation models (Figure 4). After data sets are entered into the collaborator's data base, the required data for the model-specific data base can be extracted, and the user can access the data by specifying the unique identification codes for institute, site, experiment, treatment, and weather station. The DBMS will retrieve the data from the model-specific data base and run the crop model

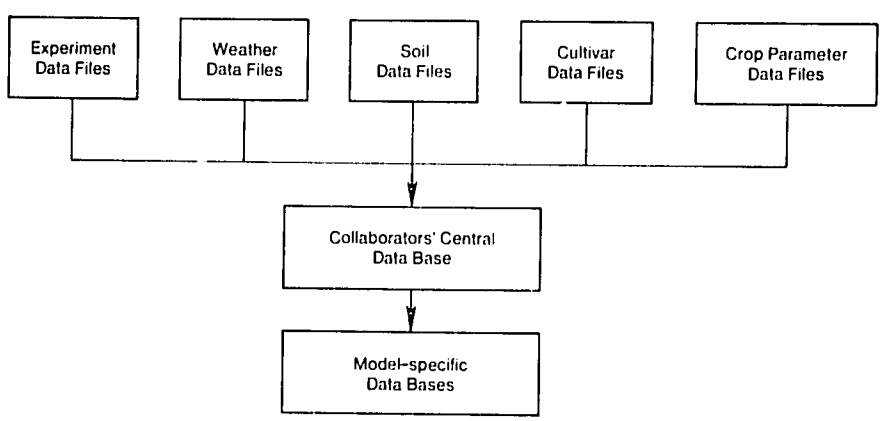


Figure 3. IBSNAT Data Base Management System.

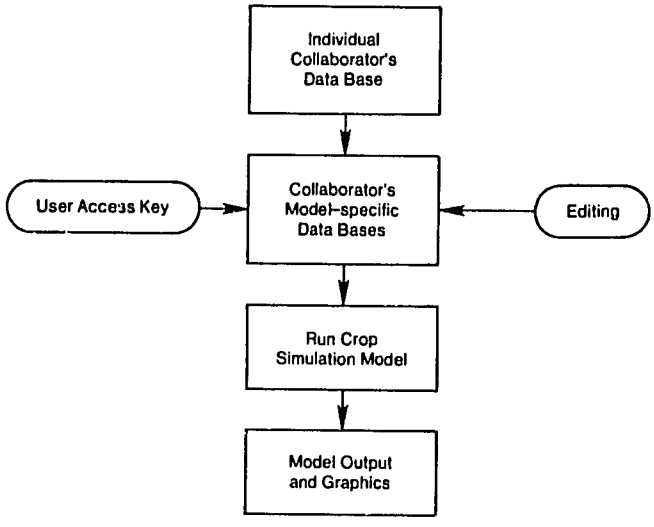


Figure 4. Individual collaborator's Data Base Management System.

simulation software program. The final simulated crop output can be printed in a standardized format. The IBSNAT collaborators can then run special graphics of simulated crop growth and other model outputs.

IBSNAT Crop Models

The IBSNAT crop models are designed to have global applications. For several of IBSNAT's ten crops, models do not yet exist or are in the early stages of development. For this report, the IBSNAT crop models are categorized into three groups.

A. First, there are models that already exist, and are available for calibration and testing.
B. Second, there are models that are partially developed, and will require collection of minimum data sets for further model development.
C. Third, there are models in the conceptualization stage.

The IBSNAT crop models are constructed to be independent of, and be able to accommodate differences in locations, seasons, crop cultivars, and management systems. The accommodating characteristics of IBSNAT crop models, provided with the specific minimum set of soil, crop, weather, and management data, enables the prediction of performance for any crop production system at any location and season. In order to predict a crop's potential, IBSNAT crop models require the following information.

1) The daily weather data consisting of maximum and minimum air temperature, solar radiation, and precipitation. If other data are required special arrangements must be made to collect them.
2) The standard soil description including data of key soil properties as a function of depth.
3) Information on sowing date, plant population, irrigation amounts and dates, and fertilizer amounts and dates.
4) Genetic information related to maturity type, photoperiod sensitivity, and yield components needed to evaluate optimum efficiencies within the constraints of weather and soil.

The intent is to use simulation models to assess crop performance in locations where the crops have never been grown. This will enable user countries to assess the suitability of particular lands for specific crops, estimate productivity of the land, and prescribe soil and crop management practices to obtain optimum production for specified conditions.

Operational models for wheat, maize, and soybeans are currently available for testing.

Table 5 lists the current status of each IBSNAT crop model for the cereals, grain legumes, and root crops. The following sections describe the progress and stages of their development.

Cereals

The wheat and maize crop models used by IBSNAT were initially developed by the USDA Agricultural Research Service scientists in Temple, Texas. Both models, commonly referred to as CERES or Crop Environment Resource Synthesis models, simulate crop growth and development from crop phenology,

Table 5. Ten IBSNAT crops selected for model development.

Crop Models	*Milestone Achieved**
A. Cereals	
Wheat	8
Rice	5
Sorghum	5
Maize	8
B. Grain Legumes	
Soybeans	8
Peanuts	5
Phaseolus Beans	4
C. Root Crops	
Potatoes	3
Cassava	2
Aroids	3

*Milestone of activities for IBSNAT crop model development are:
(1) Establish minimum data set.
(2) Identify collaborators for crop modeling.
(3) Establish design criteria for computer model.
(4) Conceptualize the model.
(5) Quantify model coefficients.
(6) Write computer program for model.
(7) Calibrate and test model against design criteria.
(8) Model available for validation run with data.
(9) Model operational.

soil, and daily weather data. The maize and wheat models have been modified to interface directly with the IBSNAT Data Base Management System.

The simulation models currently being developed for rice and sorghum will similarly have their input formats compatible with the output format of the IBSNAT DBMS. Rice and sorghum models are categorized as crop models that are partially developed. They require further development to include the characteristics that have been established for IBSNAT crop models.

The following sections describe the current status of each of the IBSNAT crop models for the four cereal crops: wheat, rice, sorghum, and maize. The report on the maize model is more extensive than that for the other cereals. It reflects the progression of activities from verification of the model's logic to its calibration and testing with data sets.

Wheat

The CERES Wheat Model, tested with a nitrogen dynamics component for use in tropical, subtropical, and temperate locations, is currently being coordinated by D. C. Godwin of the International Fertilizer Development Center in Muscle Shoals, Alabama, USA. Collaborators in Burundi, Pakistan, and the Philippines have begun or are planning to collect minimum data sets. Data collection from regional and international organizations such as the Arab Center for Studies of Arid Zones and Dry Lands (ACSAD) in Damascus, Syria; and the International Center for Agricultural Research in the Dry Areas (ICARDA) in Aleppo, Syria have also been initiated.

At the planned workshop on systems simulation and crop modeling in Amman, Jordan, the CERES models for wheat and maize will be demonstrated, and then tested with each participating collaborator's own minimum data set and the IBSNAT Data Base Management System. The workshop is scheduled for ten days in November 1985, and is being sponsored by ACSAD, the University of Jordan, and IBSNAT.

Rice

An agreement with the ARS in Temple, Texas during 1983 and 1984 permitted researchers' studies on the effects of photoperiod on twelve rice varieties using Duke University's phytotron. The rice study was coordinated by J. T. Ritchie who is now at Michigan State University. The results of the ARS studies will be used for developing the phasic component of the rice model. Phenologic characteristics are necessary to determine the genetic coefficients of each variety used in model calibration and testing with the minimum data sets generated from field experimentation.

In order to review the availability and status of current rice models, and to formulate plans for development and calibration of an IBSNAT rice model, researchers from IFDC; the Universities of Mississippi, Arkansas, Florida, and Hawaii; Michigan State University; and the ARS in Temple, Texas met in March 1985, at the IFDC headquarters in Muscle Shoals, Alabama. As a result of that meeting, a rice model with a similar structure as CERES maize and wheat is being developed by researchers at the University of Hawaii and Michigan State University.

Planting of field experiments to calibrate the model are planned at sites on the Hawaiian islands Kauai and Maui. These experiments will be planted during different seasons to study the effects of temperature, day length, and solar radiation on the phasic and growth components of the IBSNAT CERES Rice Model. The following five rice varieties out of the twelve used in earlier phytotron studies will be planted in upcoming experiments.

a) Kwang-chang-ai variety with high photoperiod sensitivity.
b) Bellemont variety with low photoperiod sensitivity.
c) Labelle variety with a short juvenile phase.
d) Starbonnet variety with a long juvenile phase.
e) 'IR-36' variety with an intermediate juvenile phase.

Seed materials have been received from the ARS station in Beaumont, Texas. The field experiments in Hawaii are scheduled to be installed during September to November 1985.

Minimum data sets for rice are expected from Thailand, Malaysia, Indonesia, the Philippines, and the United States.

Sorghum

Sorghum, an important grain of the semi-arid tropics and subtropics, is commonly grown in areas where moisture is in short supply.

The early development and testing of simulation models for sorghum were reported by researchers both in Texas, and at ICRISAT in India. The SORGF is an example of a sorghum model which had its origin in the United States and was modified by scientists at ICRISAT. Further development of the sorghum model is necessary for its compatibility with the collaborators' needs and the IBSNAT DBMS. Support for this collaborative effort will be provided by ICRISAT and Michigan State University. The sorghum model development is anticipated to begin during the 1985–86 period. Researchers at Kansas State University and other interested institutions may be consulted from time to time, as the need arises.

Sorghum data collection sets are expected from India, Venezuela, Thailand, and several ACSAD countries.

Maize

CERES Maize Model Predictions. The Crop Environment Resource Synthesis (CERES) Maize Model has been successfully tested with data from the Benchmark Soils Project's experiments in Indonesia, the Philippines, and Hawaii. Data from the Maui Soil Climate Project was also tested.

Prior to conducting the validation tests, the CERES maize model was verified and calibrated with data from the tropics. First, the logical and mathematical correctness of the model was tested on low nitrogen and low water conditions, to eliminate negative values for yield and nutrient concentrations. The model was subsequently calibrated and adjusted for (i) thermal time computation; (ii) maize genotype coefficients; (iii) optimum temperature for photosynthesis; (iv) the effect of minimum temperature on grain filling; (v) the effect of nitrogen deficiency and water stress on grain numbers; (vi) a soil-specific nitrogen mineralization constant; and (vii) an interactive term to accommodate the effect of other nutrients on crop growth when water and nitrogen are simultaneously limited.

The model validation process involves running the model with independent data. Thus, none of the experimental data used for model building or model calibration were used for model validation. Qualitative evaluation generally involves graphical and tabular display of observed and simulated values. A "good" model has less scatter around the 1:1 line, and the points are evenly distributed on either side of the 1:1 line. A "good" model is built to provide results which simulate outputs from a real system, hence statistical analysis used for simulated results is similar to that used to evaluate data from actual systems. A review of the literature revealed that no general form of statistical analysis has been recommended nor is recognized for predictions by simulation models.

A model is constructed for a specific purpose, and therefore the analysis must be model specific. Model predictions have been evaluated a) through qualitative comparisons of observed and simulated yields with the visual aid of graphs and tables; and b) by the Freese chi-square test.

Tropeptic Eutrustox Sites. The CERES Maize Model was used to simulate six experiments on two Tropeptic Eutrustox sites in Hawaii. The phenological events and grain yield predictions were compared with observed results (Table 6 and Figure 5).

The model prediction of the number of days to silking, at the most, was four days more than the observed days to tasseling. The model predicted days to silking, which is the end of vegetative stage, but it did not predict days to tasseling. However, the experimental data did not have observed days to silking, and hence relied on days to tasseling as a substitute for silking (Table 6). The model accurately predicted the days to anthesis for winter and summer plantings at both the Waipio and Molokai sites in Hawaii. The observed difference of days to tasseling for winter and summer plantings at Waipio was 14 days, and the model predicted 13 days difference. Similarly, for both observed and simulated results at the Molokai site, the difference was about 16 days. At the Molokai site, in addition to winter and summer differences, the model also predicted the delay in days to anthesis (Table 6).

The number of days to physiological maturity was generally underpredicted by the model. However, it may well be that the days to physiological maturity, which requires destructive sampling and observance of the black layer, was determined late in some of the experiments. Thus, the model prediction seems to be reasonable. For the MOL-N20 experiment, the physiological maturity date was not available. Although the observed phenological dates do not have any variance term associated with them, the standard deviation would be about two days for summer plantings and probably more for the winter plantings.

There was much scatter about the 1:1 line for the grain weight prediction (Figure 5A). In general, the model did better predicting kernels ear^{-1} (Figure 5B). Overpredictions in kernel numbers were principally

Table 6. Measured and simulated number of days to silking and days to physiological maturity, with the observed data from Tropeptic Eutrustox sites in Hawaii.

		Days After Planting			
		Silking[a]		*Physiological Maturity*	
Site/Block	*Planting Date*	*measured*	*simulated*	*measured*	*simulated*
WAI-J84	06/28/84	60	64	113	115
WAI-F10	11/17/82	74	66	149	146
MOL-L10	06/08/82	63	64	122	114
MOL-M10	06/24/80	65	69	131	125
MOL-N20	12/02/82	81	84	—	126

[a]Actual measured values are days to 50% tasseling.

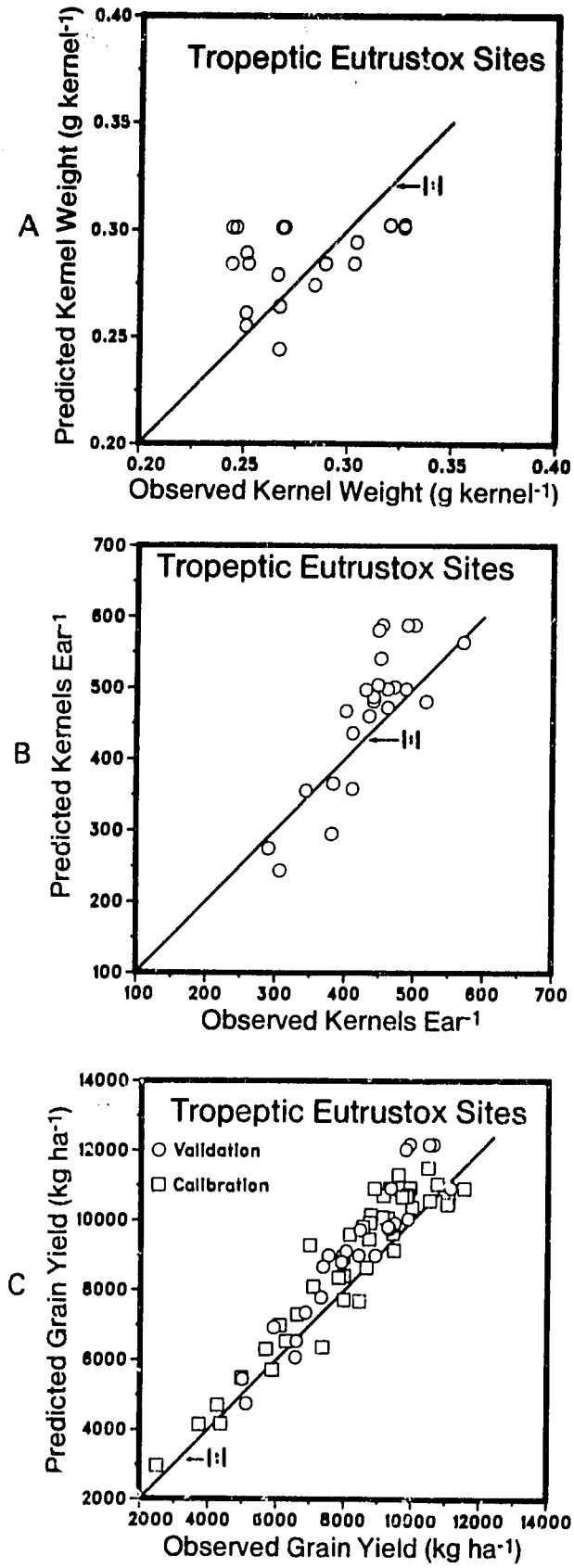


Figure 5. Comparison of observed and simulated (A) kernel weights, (B) kernel numbers, and (C) grain yield on Tropeptic Eutrustox sites.

those from the high nitrogen fertilizer treatments. Furthermore, factors which influence kernel numbers such as trace element deficiencies, pests, diseases, and weeds were not considered by the model.

In experiments used for model validation, grain yield predictions were similar to the predictions for the calibration experiments (Figure 5C). A better fit between observed and simulated results would have been possible if the model had been adjusted in the calibration stage to "fit" the experimental data. However, the adjustments, made on a logical basis, were designed to minimize the need for future model calibrations when factors not currently simulated into the model are later incorporated.

Typic Paleudult Sites. Data from five different sites in Indonesia and the Philippines were used to test the CERES Maize Model. In the calibration of the CERES Maize Model none of the experiments from Typic Paleudult sites were used. Thus, the model was used to simulate results obtained from a vastly different soil family located approximately 5°S latitude.

The model was able to predict yields ranging from 2,500 to 10,000 kg ha^{-1} (Figure 6). In general, the model predictions were higher than the observed values.

Hydric Dystrandept Soils. Validation tests on Hydric Dystrandept soils involved experiments from one site in Indonesia, three sites in the Philippines, and two sites in Hawaii.

The seasonal variation in days to tasseling was due to latitudinal differences, and had ranges of 5 days in Indonesia, 10 to 12 days in the Philippines, and as high as 19 days in Hawaii. Likewise, the model prediction for differences in days to anthesis were 5 days in Indonesia, up to 12 days in the Philippines, and as high as

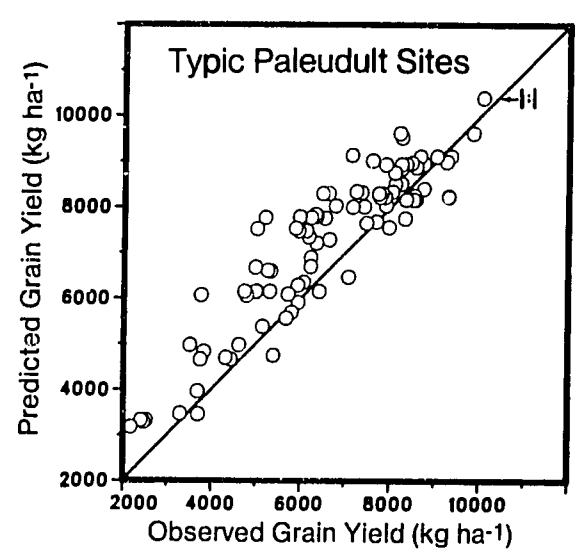


Figure 6. Comparison of observed and simulated grain yields on Typic Paleudult sites in Indonesia and Philippines.

19 days for the Hawaii experiments. The model accurately simulated the effect of seasons on the phenological development of the maize plant. Maize cultivar 'X304C' (Pioneer Hi-bred International) was planted in Indonesia and the Philippines, while the cultivar 'H610' (University of Hawaii) was grown in Hawaii. The CERES Maize Model also accurately simulated the genetic differences between the two cultivars.

The model correctly predicted grain yields of 3,000 to 10,000 kg ha^{-1} (Figure 7), which were relatively higher than the observed yields for the six Hydric Dystrandept sites.

Simulation Modeling for Transfer. CERES Maize Model predictions for phenological development and grain yield were not site specific (Figure 8) as demonstrated by model simulation of the complex interactions between genotype, environment, and management during crop growth. Validation tests of the CERES Maize Model along the slopes of Mount Haleakala in Maui further illustrates the site nonspecificity of the model (Tables 7 and 8).

The model accurately simulated a delay of 56 days in physiological maturity at the highest elevation (Table 7) relative to the lowest and warmest site. The simulated grain yields for the Maui sites were within one standard deviation of the actual mean yield (Table 8). The model predicted lower yields for the highest elevation site as it received only 80% of the total radiation compared with the two lower sites. Simulated total above ground biomass of the two experiments were within one standard deviation of the observed mean. However, at the intermediate elevation the simulated value was higher than the actual.

The CERES Maize Model predicted phenological development, kernel weights, kernels ear^{-1}, and grain yield in a wide range of environments. It performed equally well in a wide range of climates and soils including Oxisols, Ultisols, Andisols, and Mollisols. The sites ranged from 5°S latitude to 21°N latitude and 77 to 800 meters above sea level. The observed grain yields on these sites ranged from 2,000 to 11,500 kg ha^{-1}, the days to anthesis ranged from 48 to 100 days after planting (DAP), and physiological maturity varied from 97 to 176 DAP.

The CERES Maize Model has considerable potential as a tool for agrotechnology transfer among a wide range of agroenvironments in the tropics. Prediction of crop yields and intermediate phenological events also permits evaluation of cultivars, and alternative management practices such as planting date and planting density.

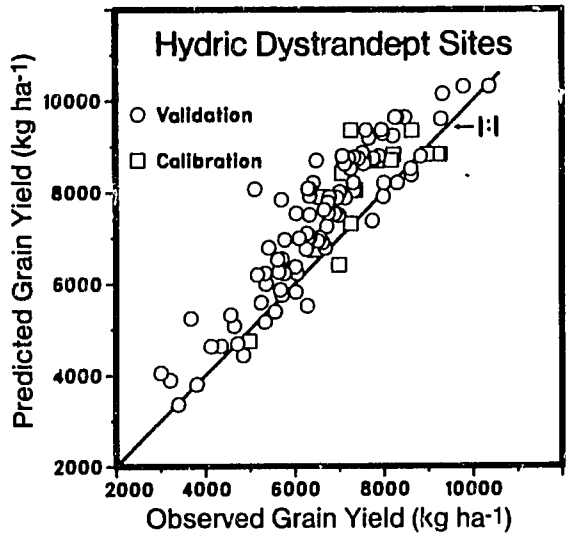
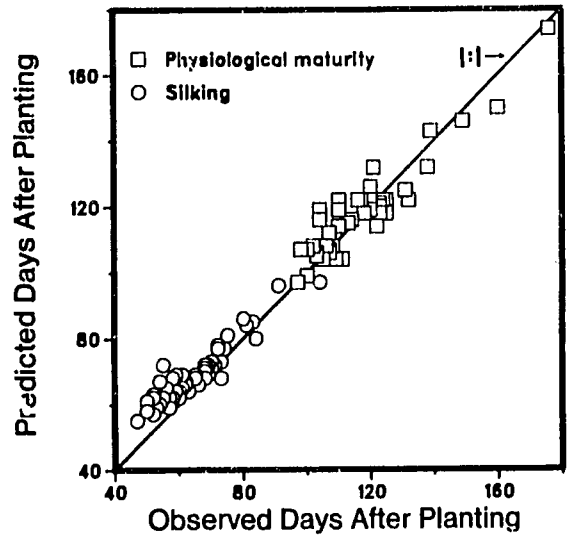


Figure 7. Comparison of observed and simulated grain yields as obtained from calibration and validation of the CERES Maize Model on Hydric Dystrandept sites.



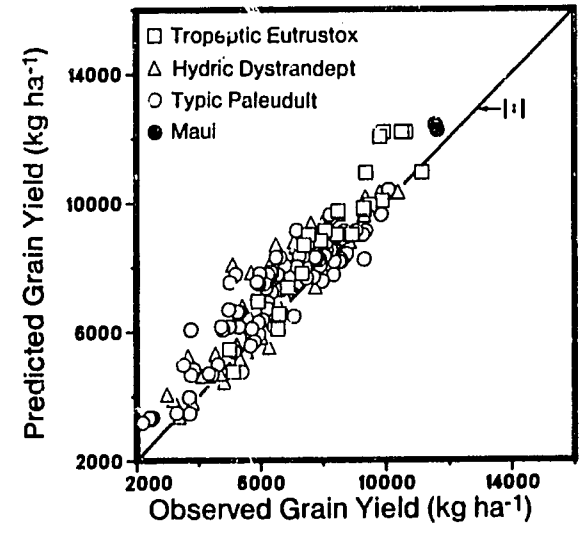


Figure 8. A comparison of observed measurements and simulated values for phenological events and for yield components.

Table 7. Comparison of observed and simulated phenological events for 'X304C' cultivar on the slopes of Mount Haleakala, Maui, Hawaii.

Elevation (m)	Days After Planting[a]							
	Emergence		End of Juvenile Stage		Silking		Physiological Maturity	
	obs[b]	sim[c]	obs	sim	obs	sim	obs	sim
77	6	5	23	25	62	67	120	119
340	7	5	28	28	73	73	138	132
800	9	7	42	38	104	97	176	174

[a]Planted on 24 April 1984.
[b]Observed values are from Maui Soil Climate Project 1984, D. P. Bartholomew's unpublished data.
[c]Simulated values from crop model.

Table 8. Comparison of observed and simulated yields for 'X304C' cultivar on the slopes of Mount Haleakala, Maui, Hawaii.

Elevation (m)	Grain Yield ($kg\ ha^{-1}$)		Above Ground Biomass ($kg\ ha^{-1}$)	
	observed[a]	simulated[b]	observed	simulated
77	11533 ± 860	12338	25025 ± 2145	23699
340	11600 ± 994	12234	21033 ± 1898	*25182
800	9178 ± 1654	9009	18731 ± 4659	22584

[a]Observed values are from Maui Soil Climate Project 1984, D. P. Bartholomew's unpublished data.
[b]Simulated results are within one standard deviation of the observed mean, except for value with asterisk.

Grain Legumes

Responsibility for development of models for soybeans, peanuts, and *Phaseolus* beans has been assigned to the University of Florida. IBSNAT collaborators J. W. Jones and J. W. Mishoe of the Agricultural Engineering Department, and K. J. Boote of the Agronomy Department are the key researchers involved in this effort.

Soybeans

The soybean model version 5.0, SOYGRO, is operational, available for calibration and testing, and ready for use by collaborators. The following report on SOYGRO was prepared for this progress report by the researchers at the University of Florida.

SOYGRO: Soybean Crop Model for Technology Transfer Using Microcomputers. Agricultural scientists are frequently asked how a crop or a crop cultivar might perform at a particular location. Questions also arise concerning crop management. The complex interactions between soil, weather, and plant factors make questions like these difficult to answer, and then only in qualitative terms. Recent advances in computer technology, however, have made quantitative evaluations more possible.

One of the primary goals of IBSNAT is to acquire and test computerized models of several crops using a network of experimental sites with different soil and weather characteristics. Once tested, these crop models will provide a rapid and effective means for transferring crop production technology to developing as well as developed countries around the world. The SOYGRO V5.0 is an example of such a model that will be adapted and tested as part of the IBSNAT program.

During 1979 through 1983, the researchers at the University of Florida were developing the original soybean crop growth model, SOYGRO V4.2 to improve irrigation and pest management practices in Florida. The SOYGRO V4.2 model included soil water, insect, irrigation, pesticide tactics; and economic submodels. It was tested at two locations in Florida to assess the profitability and risks associated with various irrigation and pest management practices. SOYGRO V4.2 included a soil water balance model developed for light-texture soils and was focused on determinate cultivars normally grown in the southern United States.

In 1984, a new version of the model, SOYGRO V5.0, was developed to overcome the limitations that restricted the application of the V4.2 model to determinate cultivars and Florida soil conditions. A soil model developed in Texas for use on a large set of soils was adapted for the new version. A submodel for predicting vegetative and reproductive stages of determinate and indeterminate soybean cultivars was also added to the new model. The overall structure of SOYGRO V5.0

for predicting crop growth and yield remained the same as that of version 4.2, although some parameters were changed based on new experimental data.

The model's growth and yield predictions were sensitive to soil, weather, and cultivar factors. Phenological development was affected by the night length and temperature, whereas growth and dry weight partitioning were affected by radiation, temperature, soil water availability, and cultivar characteristics.

The soil model is used for IBSNAT wheat and corn models, as well as soybeans, and therefore conveniently makes use of the same soil and weather data bases. The output routines are also designed to be adaptable to other models on the same computer. These common interfaces for all IBSNAT models will enhance the usability of models developed by various groups.

SOYGRO V5.0 was designed for several types of applications, each requiring a different level of user knowledge and expertise. The first level is ideal for educational and demonstrational purposes in which users can select from preprogrammed case study combinations. The model runs on an IBM-PC or compatible microcomputer, and is designed for use by those with little or no computer training or experience. A series of menu options allows the user to specify weather data, soil type, and cultivar from several available data files on the diskette; and the field can be irrigated if desired. The model then simulates crop growth and lists year-end summary information such as yield, production costs, profit, and irrigation amount. The user has the option of observing a graphic display of two rows of plants for the simulated crop. The display demonstrates weekly canopy development with row spacing, plant height, and leaf area drawn to scale (Figure 9). Users can also graphically display seasonal changes in plant and soil variables, and print these out for their permanent record. Figure 10 shows simulated total canopy weight and seed weight for a soybean crop grown under 1978 weather conditions in Gainesville, Florida, and for a Lake fine sand (hyperthermic, coated, Typic Quartzipsamment). Actual data are also plotted in Figure 10 for direct comparison of the model and the experimental results.

A second level of use allows IBSNAT collaborators to compare or validate their own soil, weather, and crop data with simulated data from SOYGRO V5.0. The modification of input data required for this level of use can be carried out with any of the microcomputer's standard editors or word processors. Collaborators' crop data can be plotted for direct comparison with simulated results, such as that shown for the Gainesville data in Figure 10. Once standard formats for the IBSNAT data base have been defined, the model will be modified accordingly. This will simplify the process

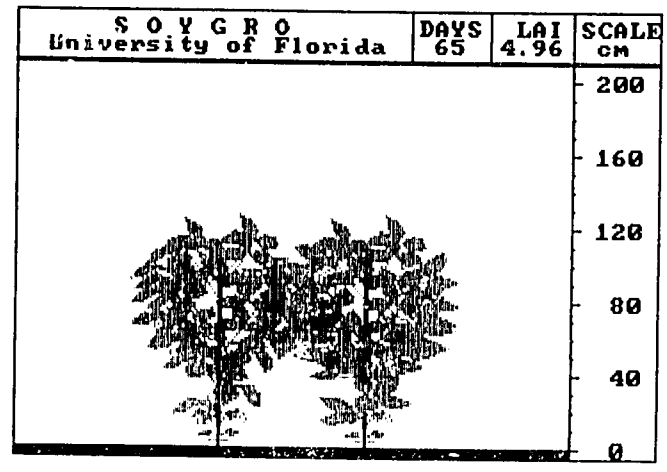


Figure 9. Canopy development of soybean plants at 65 days, with row spacing, plant height, and leaf area index shown to scale.

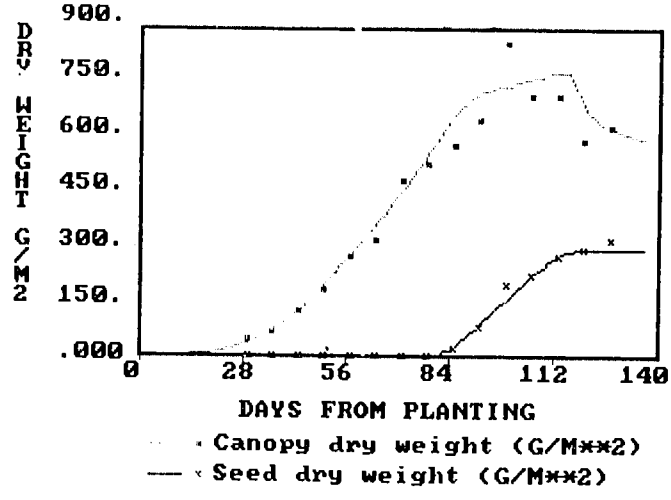


Figure 10. Actual measurements (■ and ×) and simulated values (dashed lines) of canopy and seed dry weights for soybean plants grown under 1978 weather conditions in Gainesville, Florida, and for a Lake fine sand (hyperthermic, coated, Typic Quartzipsamment).

of simulating any IBSNAT experiment, and allow direct comparison of simulated and experimental results.

A third level of use, requiring more detailed knowledge of how to change data and computer codes, allows for modification of the model. For example, a collaborator may wish to study the effects of a foliar disease or of soil phosphorous nutrition on crop growth and yield. These potential stress factors are currently not included in the model but could be added with appropriate experimental data and changes in the computer program. The model is also being documented so that the addition of other stress factors on photosynthesis and partitioning can be easily included. In addition, the model can be changed to simulate other pulse crops such as peanuts. This third level of use requires more

knowledge of crop and soil interactions and more user time than the first two levels.

A fourth level involves the linkage of SOYGRO V5.0 with application-specific packages. For example, the crop model could form the basis for evaluating irrigation and pest management decisions during a season, evaluating investment decisions, forecasting yield, or predicting the effects of soil erosion. This level of use involves more mathematical, statistical, and economic considerations than the other levels, as well as additional computer programming. At this level, the SOYGRO V5.0 model will become a submodel for more comprehensive systems and may require the use of larger computers to facilitate the simulation of many crop seasons to answer specific questions and to provide recommendations based on risk considerations.

The potential use of computer models to transfer crop production technology presents an exciting challenge. The goal is to develop the SOYGRO technology for two additional important food crops, peanuts and *Phaseolus* beans, and to test the three models using data collected throughout the IBSNAT network of experimental sites. It is hoped that the effort will evolve into a holistic system that uses computer technology to match crops, soils, climates, and management capabilities with a high degree of confidence to help ensure stable, low-risk food production.

Peanuts

The peanut model, categorized as partially developed, has evolved further using a model structure that is similar to SOYGRO. Boote included plant growth processes, a water balance model developed by J. T. Ritchie, and a partitioning of photoassimilates with a carbon balance approach. Model calibration will commence with existing data sets on the composition of plant parts, thresholds for phenology stages, partitioning, and other key crop parameters. If the anticipated structure of the SOYGRO model is fairly generic, then with a few modifications, the model can be adapted to peanuts and other grain legumes.

Peanut data collection sets are expected from India, Niger, Thailand, and Indonesia.

In January 1985, at a national meeting on peanuts at the University of Georgia, C. A. Jones of ARS in Temple, Texas, and J. W. Jones of Florida shared with participants the concept of a minimum data set for peanut crop modeling. As a result of that meeting, several requests have been received from interested researchers for the data forms contained in the IBSNAT Technical Report 1.

Beans

A simulation crop model for *Phaseolus* beans is at the conceptual stage of development. Its progress is expected to follow a similar path as the SOYGRO model. Communication has been established with J. W. White and P. G. Jones of CIAT, regarding preliminary meetings with University of Florida researchers Jones, Mishoe, and Boote, to explore potential collaboration for bean crop model development. According to the IBSNAT collaborators in Florida, data on crop phenology and dry matter or biomass production are essential for model development. In order to estimate biomass production, the growth data, information on solar radiation effects, the temperature, leaf area index, and leaf nitrogen concentration on photosynthesis are needed.

The potential collaborators interested in model testing are from countries in Asia, Latin America, and Africa.

A workshop on systems simulation and crop modeling for the grain legumes has been scheduled for the latter part of 1986.

Root Crops

Of all the IBSNAT crops, models for root crops are the least developed. Much of the model development activities are still in the conceptualization stage, with potatoes having received more attention than cassava and the aroids.

Potatoes

Model development and testing for potatoes are being conducted by E. E. Ewing of Cornell, P. J. Sands of CSIRO, and J. T. Ritchie of Michigan State University. Through his association with researchers at the International Potato Center (CIP), Ewing's research programs involve selecting and evaluating potato cultivars for the warm, lowland tropics. His programs also include modification and testing of the Ng and Loomis POTATO model. The collaborators in this effort are Hawaii and Tunisia.

The potato model at CSIRO was patterned after an earlier model for sweet potato. Sands has labeled the CSIRO potato model TUBERS. Current work has been on verification of the model programming and its calibration.

Using their experience gained during the development of the CERES models, Ritchie and his staff at Michigan State are reviewing existing models, and will prepare a conceptualization of a prototype potato model. Utility of the MDS and IBSNAT DBMS is essential in determining which model or combination of models IBSNAT will adopt.

Cassava

While cassava is widely grown throughout the tropics and subtropics, no operational simulation model for it

exists. It is anticipated that potential collaboration for model development will more likely be at the international or regional agricultural research centers. Researchers at CIAT have previously expressed interest in the cassava model development. However, it is also conceivable that national collaborators may become principal partners in model development for cassava.

Aroids (taro)

Through the direction of H. A. Nix, researchers at CSIRO in Canberra, Australia have initiated studies on both potatoes and aroids. Of the family of aroids, taro crop will receive the most attention. Collaborators from Fiji, Hawaii, and Southeast Asian and South Pacific countries will be involved in data generation and model development.

Data Generation for Model Calibration and Testing

Hawaii Progress Report

Genetic Coefficients and CERES Maize Model Calibration

A corn experiment was installed in November 1983 to obtain data to calibrate the CERES Maize Model, and to observe the effects of nitrogen (N) fertilization on leaf area development, phenology, and grain yield for two maize cultivars. The IBSNAT experiment site is located on the island of Oahu, Hawaii (21°25′N and 158°W), and has soil of Wahiawa silty, clayey loam (clayey, kaolinitic, isohyperthermic, Tropeptic Eutrustox) with soil parent material of weathered, olivine basalt.

Data for soil water, crop growth, leaf development, and grain yield components of the CERES Maize Model were obtained using a randomized complete block design. Nitrogen treatments applied at levels of 0, 50, and 200 kg ha^{-1}, for cultivars 'X304C' and 'H610', were replicated three times.

At the three nitrogen treatments, changes in soil water content with time were measured with a neutron probe at various depths (Table 9). Simulated values of soil water content were within one standard deviation of the observed values. Table 10 compares the predictions of the calibrated model to the observed phenological events of this experiment. Comparisons of simulated and observed leaf area index (LAI) and the above ground biomass for several times after planting are presented in Figures 11 and 12. The results show that the LAI and biomass increase with increasing levels of N fertilizer for both maize cultivars 'H610' and 'X304C'. Table 11 compares data collected from this experiment with simulated values for leaf weights, at three levels of nitrogen application.

The experimental results were used to modify the genotype specific coefficients, and to run calibration tests for the CERES Maize Model. Model calibration and validation tests were applied to the intermediate

Table 9. Comparison of experimental measurements and crop model simulations for soil water content, at tassel initiation (Julian date 2) and during tasseling (Julian date 38).

		Volumetric Soil Water Content (cm^3/cm^3)			
		Julian date 2		*Julian date 38*	
Nitrogen Applications ($kg\ ha^{-1}$)	*Soil layers (cm)*	*measured*[a]	*simulated*	*measured*	*simulated*
200	0–10	0.24 ± .03	0.26	0.27 ± .03	0.29
	10–30	0.31 ± .02	0.33	0.30 ± .03	0.32
	30–50	0.37 ± .02	0.36	0.32 ± .02	0.33
	50–70	0.38 ± .02	0.38	0.36 ± .01	0.35
	70–90	0.38 ± .01	0.38	0.35 ± .02	0.35
	90–110	0.38 ± .01	0.39	—	0.37
50	0–10	0.27 ± .03	0.26	0.28 ± .03	0.28
	10–30	0.34 ± .02	0.33	0.32 ± .02	0.33
	30–50	0.35 ± .02	0.36	0.35 ± .02	0.33
	50–70	0.39 ± .02	0.38	0.36 ± .02	0.35
	70–90	0.39 ± .02	0.38	0.37 ± .02	0.35
	90–110	0.39 ± .01	0.39	—	0.37
0	0–10	0.24 ± .02	0.26	0.27 ± .03	0.29
	10–30	0.34 ± .02	0.33	0.32 ± .02	0.33
	30–50	0.35 ± .02	0.36	0.34 ± .02	0.33
	50–70	0.39 ± .02	0.38	0.36 ± .02	0.35
	70–90	0.39 ± .02	0.38	0.37 ± .02	0.35
	90–110	0.39 ± .01	0.39	0.37 ± .02	0.37

[a]Measured values are ±1 standard deviation.

Table 10. A comparison of the observed phenological events and calibrated crop model predictions for maize cultivars 'X304C' and 'H610'.

Corn Phenology	Nitrogen Applications (kg ha⁻¹) 0		50		200		0		50		200	
	Days After Planting											
	obs[a]	sim[b]	obs	sim	obs	sim	obs	sim	obs	sim	obs	sim
	Cultivar 'X304C'						Cultivar 'H610'					
Emergence	7	5	7	5	7	5	7	5	7	5	7	5
Tassel initiation	35	35	35	35	35	35	32	34	32	34	32	34
Silking	79	81	79	79	79	78	74	79	74	76	74	75
Grain fill onset	—	—	—	—	95	89	—	—	—	—	89	87
Physiological maturity	138	139	138	135	138	136	134	133	134	133	134	133

[a]Observed field experiment values.
[b]Simulated crop model values.

Table 11. Comparison of leaf weight measurements and model simulated values for maize cultivars 'X304C' and 'H610', at three levels of nitrogen application.

Days After Planting	Nitrogen Applications (kg ha⁻¹) 0		50		200	
	Leaf Weights of Plants (g)					
	measured[a]	simulated	measured	simulated	measured	simulated
Cultivar 'X304C'						
33	3.6 ± 0.7	3.9	4.0 ± 1.0	4.1	3.9 ± 0.6	4.1
71	39.9 ± 4.7	32.4	51.8 ± 5.0	51.6	56.8 ± 6.5	60.0
98	44.2 ± 1.7	33.3	54.4 ± 3.5	54.4	58.3 ± 5.0	61.8
105	50.4 ± 5.0	32.9	55.9 ± 6.0	53.8	60.5 ± 3.2	61.3
118	36.4 ± 3.0	32.1	46.0 ± 6.0	52.5	53.2 ± 6.7	59.7
Cultivar 'H610'						
33	4.2 ± 0.1	4.3	3.6 ± 0.8	4.6	4.1 ± 1.0	4.6
71	37.6 ± 6.0	30.4	42.1 ± 7.2	47.6	56.7 ± 9.0	53.9
98	46.5 ± 6.5	30.4	48.2 ± 3.0	48.9	65.8 ± 4.2	55.0
105	43.8 ± 3.0	30.1	54.7 ± 4.0	48.3	62.8 ± 6.5	54.3
118	31.5 ± 6.5	29.2	43.5 ± 3.0	46.9	54.6 ± 8.7	52.9

[a]Values are ±1 standard deviation.

stages of the crops' growth and development, as well as on the final crop yields. More experimental field data, collected from many other sampling sites, would allow further specific calibrations and tests for the CERES Maize Model.

Venezuela Progress Report

Simulating Effect of Planting Dates on N Uptake to Test CERES Maize Model

On 10 July 1984, a maize crop was planted at the Guanipa Experiment Station to collect data sets for testing IBSNAT's CERES Maize Model in the Anzoateque region of Venezuela. The soils in this region are well-drained Ultisols situated on level topography. Weather data for the crop model was collected by a meteorological station located 200 meters from the experimental site.

The purpose of this field experiment was to assess the ability, of the then available versions of CERES maize models, to predict maize growth and performance in various parts of the country. The Venezuelan common cultivar 'FM6' was planted on Julian day 192 at a population density of 5.72 plants per square meter. The fertilizer treatments consisted of, 18 out of a possible 27, nitrogen (N), phosphorus (P), and potassium (K) combinations; with N levels of 0, 100, and 200 kg ha⁻¹; P levels of 0, 75, and 150 kg ha⁻¹; and K levels of 0, 50, and 100 kg ha⁻¹. The treatments were arranged in a randomized block design with four replicates.

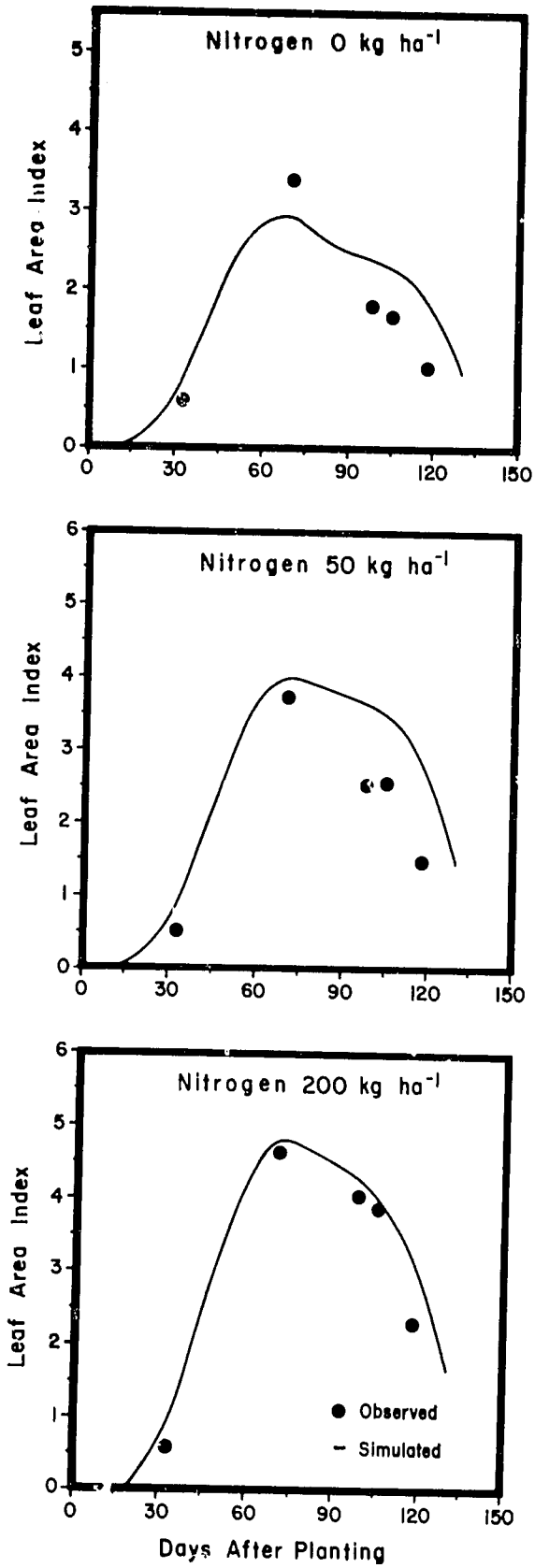


Figure 11. The maize cultivar 'H610' comparison of measured data and model simulated values for leaf area index (LAI), at three levels of nitrogen application.

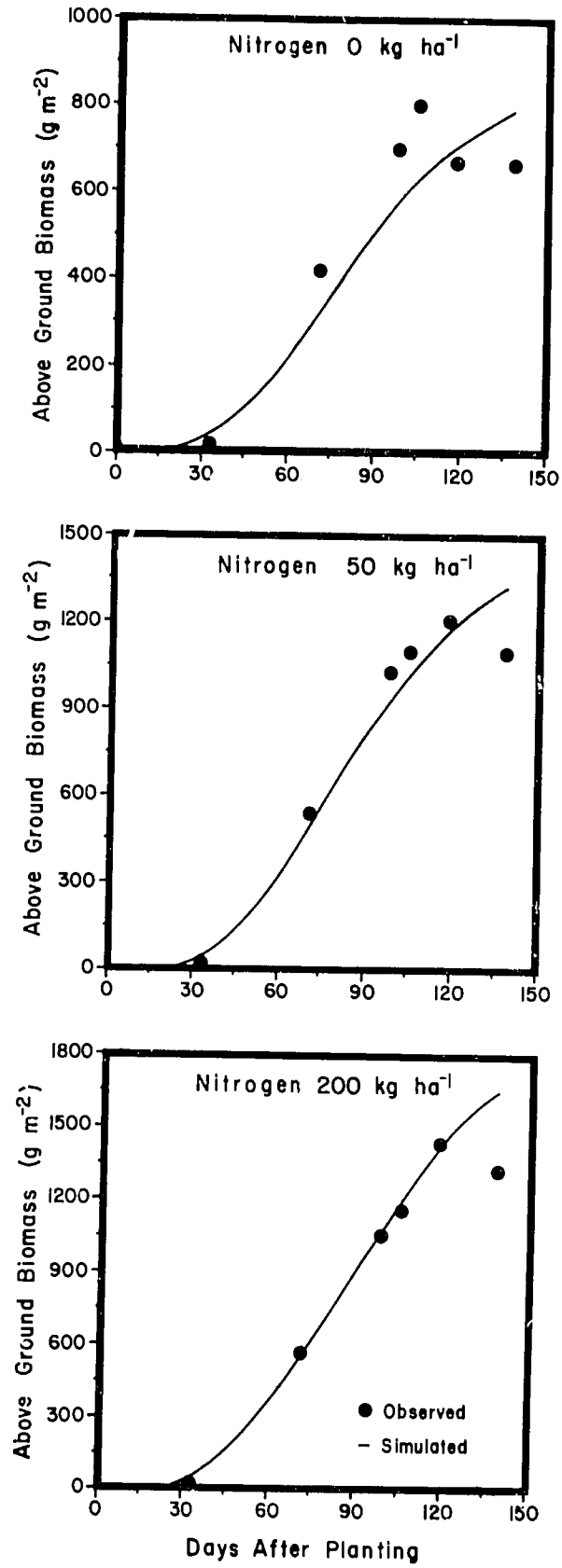


Figure 12. The maize cultivar 'X304C' comparison of experimental observations and model simulations for above ground biomass, at three levels of nitrogen application.

Instructions in the IBSNAT manual, *Experimental Design and Data Collection Procedures for IBSNAT,* were followed to collect the minimum data set required to calibrate the crop model. The minimum data set included information on the daily weather (solar radiation, maximum and minimum temperatures, and rainfall), the soil (water-holding capacity, organic matter content, and growth limiting nutrients), and the crop's genetic coefficients. Provided with this data, the CERES Maize Model simulated the effects of climate, water stress, and nitrogen supply on growth and performance of the maize cultivar.

The cultivar's measured and simulated responses to nitrogen applications under rainfed conditions are shown in Figure 13. All simulated values fall within one standard deviation of the corresponding maize grain yield measurements.

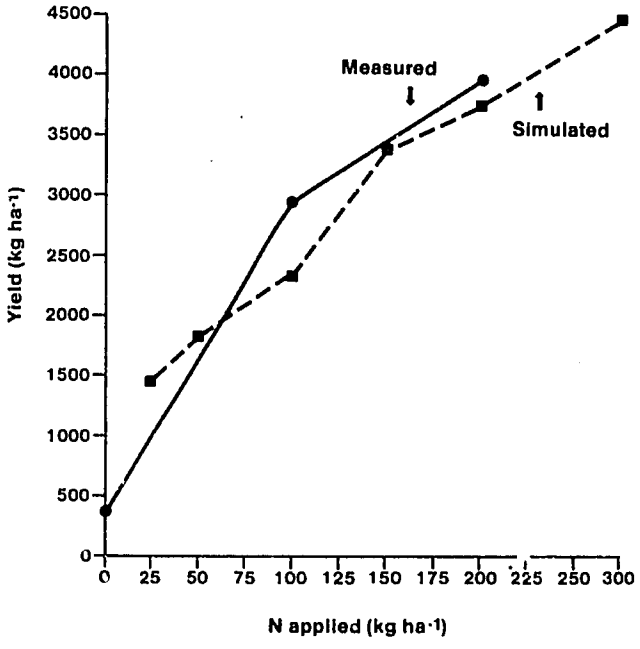


Figure 13. Comparison of measured and simulated values of 'FM6' maize yields at various levels of nitrogen application. Climatic parameters were normal and the population density was 5.72 plants per square meter.

During initial attempts to calibrate the model, this particular experimental data set revealed a number of model deficiencies. When the model was run with data from N level 0 kg ha^{-1}, negative values for nitrate (NO_3^-) and ammonium (NH_4^+) were obtained. This was due to the model's continued N immobilization of NO_3^- and NH_4^+, even when there was no mineral nitrogen to immobilize. Also, the crop model did not prevent soil N uptake when NO_3^- or NH_4^+ reached negligibly low levels. These model deficiencies were exposed because the soil in the Anzoateque region is sandy and low in organic matter content, enabling the intense rains to leach soluble nitrogen from the root zone. Corrections for the deficiencies at zero nitrogen level were made, and the model now predicts reasonable crop yields.

The effect of planting dates on maize grain yield can be simulated by the CERES Maize Model. This exercise was conducted at the "Systems Analysis and Simulation of Crop Growth for Agrotechnology Transfer" workshop held in Caracas, Venezuela, 3–14 December 1984. Using weather data from the same meteorological station, the simulated results for two planting dates are shown in Table 12.

The results demonstrate that planting dates strongly affect the plants' response to nitrogen (Figure 14). During the second planting period, an increase in days to silking, and the reduction of maximum leaf area index (LAI) with a corresponding decrease in biomass production and grain yield, reflect the unfavorable weather and poor rainfall distribution. The cumulative rainfall for the first and second planting periods was 609 and 604 mm, respectively. At the second planting date, water stress during the grain-filling period was the major factor contributing to the low yield.

Table 12. Model simulated responses of maize cultivar 'FM6' to three nitrogen levels, and at two different planting dates (Julian data 192 and 221). Plant population density is 5.72 plants per square meter.

	Model Simulated Parameters					
Nitrogen Application (kg ha⁻¹)	*Crop Yield (kg ha⁻¹)*	*Days to Silking*	*Maximum LAI*	*Plant Biomass (kg ha⁻¹)*	*Total N uptake (kg ha⁻¹)*	*Amount N in grain (kg ha⁻¹)*
First planting date (Julian day 192)						
50	1812	62	3.26	6261	29.0	14.3
100	2313	62	4.00	7591	40.5	23.7
200	3749	62	4.66	9188	66.8	46.6
Second planting date (Julian day 221)						
50	912	61	1.77	4566	32.4	13.4
100	1076	61	1.86	5350	49.7	16.0
200	1132	61	2.15	5692	70.4	17.0

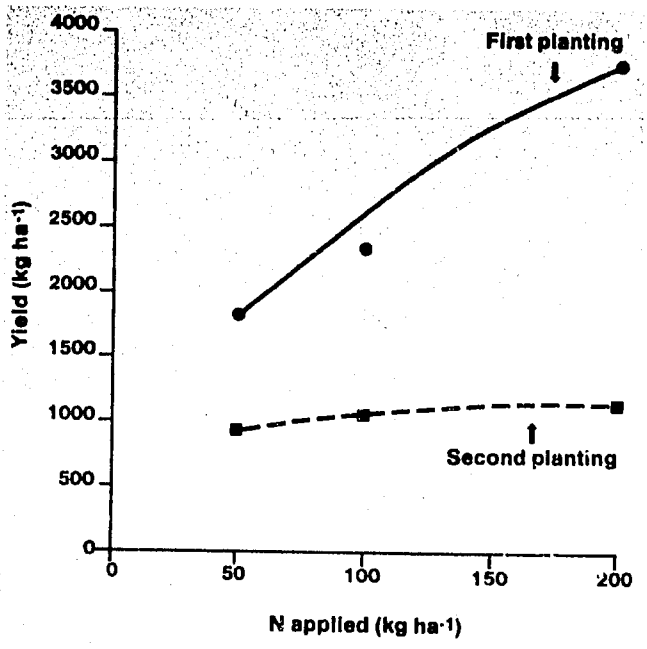


Figure 14. Simulated yield response of maize cultivar 'FM6' to applied nitrogen fertilizer at two different planting dates.

Zambia Progress Report

Maize Performance and Soil Constraints

This report of IBSNAT activities in Zambia, conducted by the University of Zambia's School of Agricultural Sciences, is a brief statement of the accomplishments on the researched effects of water availability and nitrogen supply on maize yield. The IBSNAT experimental site has soil of a clayey, mixed, isohyperthermic family of Oxic Paleustalfs.

Water supply and soil nitrogen availability are the major factors which limit maize performance in Zambia. Maize production is very dependent on rainfall and consequently susceptible to the periodic droughts. In Zambia, the erratic rainfall during the wet season affects the maize yield. When water supply is adequate, the crop performance is regulated by soil nutrient availability. However, when the water supply is limited, the effects of soil fertility become less significant, and the crop growth depends on water availability. For Zambia, it is important to quantitatively evaluate the effects of water supply on fertilizer use efficiency and crop yield.

The first corn experiment was planted on 7 December 1984, at the University of Zambia Farm near Lusaka. A split-plot design was used with nitrogen treatments in the main plots and water levels in the subplots. Data were collected in triplicate from each of four nitrogen treatments of 0, 56, 112, and 168 kg ha^{-1}; and from two irrigation treatments consisting of rain only, and rain plus supplementary irrigation. Soil samples were collected before the maize was planted, and analyzed for initial nutrient and water levels. At the time of this writing, the University of Zambia laboratory was still analyzing the nutrient levels.

Initially, the original guidelines were used because the revised version for collection of the minimum data set arrived forty days after the experiment was installed. However, upon receiving it, the data was collected as recommended in the updated guidelines. A meteorological station was set up prior to planting the maize crop, and provided data for all of the required weather parameters. The experimental period was a very wet one, with only one dry period that lasted twelve days. The experiment was harvested in late July 1985.

Collection of minimum data sets for soybeans, sorghum, wheat, and peanuts are planned for next season.

Panama Progress Report

Soil Acidity and Cassava Performance

In May 1984, the Instituto de Investigación Agropecuária de Panamá (IDIAP), also called the National Research Institute of Panamá, installed two cassava experiments as part of their IBSNAT program. The soil at the Ocu experiment site in the Province of Veraguas, is classified as a Typic Tropudult. Two experiments with ten cassava varieties were designed to investigate the influence of soil acidity associated with Ultisols in Panamá on cassava performance. One experiment was designed to study the effect of aluminum (Al) toxicity on cassava yield, and the other to determine the plants' responses to lime. Provisions were made to gather soil, crop, and weather data for the cassava crop models. Solar radiation, air temperature, rainfall, and relative humidity were monitored daily at a weather station that was installed near the IBSNAT experiment site.

The preliminary results of the first IBSNAT experiment showed that for most of the cassava varieties, a significant portion of the leaf area was associated with primary branching. For two high-yielding varieties, the leaf areas were distributed along the main stems, and less than 40 percent was associated with primary branching. Three cassava varieties had more than 40 percent of their leaf area associated with the secondary or tertiary branches. Table 13 shows the details of plant canopy development and root yield at 120 days after planting.

The field experiment data indicates that root yield is not associated with any particular branching habit, and no clear relationship exists between root yield and leaf area index. The results show that local genotypes have the potential to produce high root yields in soils of high Al content and low pH.

Table 13. The root yield performance and plant canopy development for Panama's local cassava varieties and hybrids at 120 days after planting.

Cassava Plant Varieties	*Root Yield (Mg ha⁻¹)*	*pH units (1M KCl)*	*Al^{+3} cmol(+)kg⁻¹*	*Leaf Area Distribution (%)*[a]			
				Stem	*1°*	*2°*	*3°*
Brazilena	5.38	3.7	5.3	11.6	84.8	3.6	0.0
Amarilla	6.25	3.7	4.9	21.9	38.9	34.2	5.0
Roble	6.86	3.7	4.8	73.3	26.7	0.0	0.0
Cartagenera	9.23	3.7	4.4	15.1	81.8	3.1	0.0
'C-14'	8.77	3.7	4.6	13.9	63.6	22.5	0.0
'2129'	8.55	3.7	4.7	4.9	37.5	57.6	0.0
Viejito	7.49	3.7	4.7	60.8	39.2	0.0	0.0
Roja Chiriqui	1.85	3.7	—	12.0	48.2	15.6	24.2
Calabacito	4.14	3.7	4.9	15.8	84.2	0.0	0.0
Chorrerana	6.06	3.7	—	21.3	75.8	2.9	0.0

[a]The leaf distributions 1°, 2°, 3° refer to the primary, secondary, and tertiary branching, respectively.

The phenological events for cassava were recorded, and periodic biomass evaluations were performed according to IBSNAT guidelines. The minimum data sets for cassava, collected during several seasons and from a range of agroenvironments, provide data necessary for developing the crop model. Soil sampling at different depths, and at selected times of the growing season, has been scheduled in order to monitor the dynamics of soil pH and exchangeable calcium, magnesium, potassium, and aluminum.

Burundi Progress Report

The Kajondi Farm is a seed multiplication station supported by the Government of Burundi and USAID. Seed material for potatoes, maize, wheat, and sorghum are multiplied at the farm for distribution to local farmers. Soils at the Kajondi Farm were collected and described by A. Touchet of SCS/Louisiana through the coordination of the SMSS program in 1984.

In 1984, soon after the second IBSNAT meeting in Hawaii, the USAID Mission in Bujumbura purchased an automatic recording weather station to collect the minimum weather data set. The weather station site and experimental area for wheat and maize were selected by staff of the University of Burundi and the Belgian Technical Cooperation program. In May 1985, IBSNAT assisted with the installation of the weather station.

The first maize crop is scheduled for planting in October 1985. Wheat is scheduled to be planted at an adjacent area in February 1987.

Guam Progress Report

The University of Guam has installed IBSNAT field experiments to collect data for the maize and cassava crop models. The *Experimental Design and Data Collection Procedures for IBSNAT* was followed to obtain the required minimum data sets for maize and cassava. Both crops were grown in fertilizer treatment experiments to study nutrient stresses.

Thirty years of weather information have been accumulated in Guam. The patterns for weekly and monthly temperature distributions, and the sunshine and solar radiations patterns appear regular and unchanging, except for the short periods when typhoons pass over Guam.

Guam collaborators have plans to submit their minimum data set forms, and will record the data set on diskettes and send them to IBSNAT Hawaii for model validation and development.

Thailand Progress Report

Experiments to generate minimum data sets for maize, rice, cassava, peanuts, and sorghum have been installed at fourteen national agricultural research stations in Thailand. Seven of these stations are managed by the Rice Research Division of the Department of Agriculture. Soybean experiments are also planned for the next season.

The designs, experimental plans, and planting schedules were sent to Hawaii in July 1985 for review, comments, and general information. Reports were submitted by the Department of Land Development on behalf of the collaborating Thai scientists. Completed data sets are expected to be submitted to both Departments of Land Development and of Agriculture for input onto floppy diskettes and transmittal to Hawaii. Both departments are exploring means of acquiring IBM microcomputers or compatible computer hardware to facilitate this transmittal before the harvest of the first series of experiments.

Researchers at the Department of Agriculture have expressed interest in participating in the development

of crop models for rice and cassava. Both are export crops for Thailand.

The USAID Mission's Office of Agriculture in Bangkok has been supportive of the IBSNAT collaborative research activities and information transfer between Thailand and Hawaii. That office has been offered assistance to IBSNAT, if necessary, in coordinating workshops or meetings with Thailand government agencies.

Syria Progress Report

The Arab Center for the Study of Arid Zones and Dry Lands (ACSAD) conducted two IBSNAT wheat experiments. One was an irrigated experiment at Deir Ezzor in the Euphrates Valley on a Typic Torrifluvent, and the other a rainfed experiment at Jableh located along the coast of the Mediterranean Sea on a Typic Zerochrept. Both experiments were harvested in June. For the next round of experimentation, a third IBSNAT site will be added near Izraa in southern Syria on a Typic Chromoxert.

The International Center for Agricultural Research in the Dry Areas (ICARDA) conducted IBSNAT wheat crop experiments at four locations in northern Syria. The experimental site and soil information follows.

Sites	*Location from Aleppo*	*Soil Classification*	*Annual Rainfall*
Breda	30 km SWS	Vertic or Calcic Xerochrept	280 mm
Tal Hadia	40 km SES	Typic Chromoxert	350 mm
Jinderess	80 km NWN	Typic Chromoxert	450 mm
Khanasser	90 km SE	Typic Calciorthid(?)	220 mm

Collaborators' Status of Field Experiments

The IBSNAT Project anticipates many new minimum data sets from collaborating countries that have only recently installed field experiments. These experiments and their planting schedules are shown in Appendix A. The modified Gantt charts are organized according to crop, and the collaborating countries are listed alphabetically.

Crops	*Countries*	*Experiments in Progress*
Maize	Burundi	-
	Guam	2
	Panamá	6
	Thailand	3
	USA, Hawaii	2
	Venezuela	6
	Zambia	4
Wheat	Burundi	-
	Syria	2
Rice	Panamá	2
	Thailand	6
	USA, Hawaii	3
Sorghum	Thailand	3
Soybean	Thailand	-
	USA, Hawaii	2
	Venezuela	5
	Zambia	-
Cassava	Guam	1
	Panamá	1
	Thailand	2
Potato	Tunisia	2
	USA, Hawaii	4
Peanut	India	2
	Thailand	5

Tal Hadia is ICARDA's main experiment station. All experiments were rainfed trials with wheat. They were planted in mid-November 1984 and harvested in June 1985.

UTILIZATION AND DISSEMINATION OF IBSNAT CONCEPTS

Regional Networks

During the past year, IBSNAT has been working with two large groups of nations to establish regional networks. IBSNAT is working with scientists and officials from the Association of Southeast Asian Nations (ASEAN) and Oceanic countries, to establish ASEAN Benchmark Sites Network for Agrotechnology Transfer (ABSNAT) and Oceania Benchmark Sites Network for Agrotechnology Transfer (OBSNAT).

In April 1985, representatives of the ASEAN network met in Manila to prepare a preproposal for establishment of ABSNAT. The proposal has been submitted to the ASEAN Committee on Food, Agriculture and Forestry (COFAF) for approval and implementation.

ABSNAT will be comprised of the following six ASEAN countries:

Brunei	Philippines
Indonesia	Singapore
Malaysia	Thailand

In early November 1984, the South Pacific Commission Directors of Agriculture met in New Caledonia to consider OBSNAT, and expressed unanimous support for such a network. OBSNAT will be comprised of the following 19 Oceanic countries:

American Samoa	Niue
Cook Islands	Palau
Fed. States of Micronesia	Papua New Guinea
Fiji	Solomon Islands
French Polynesia	Tonga
Guam	Tuvalu
Kiribati	Vanuatu
Mariana Islands	Wallis and Futuna
Nauru	Western Samoa
New Caledonia	

Regional networks are designed to focus on regional problems such as growing flooded rice in Southeast Asia, and aroids in Oceania. In the long run, regional networks are intended to extend systems analysis and simulation research to tree crops, animal husbandry, pest management, and commodities that are important to a region.

Two existing regional networks, Arab Center for the Studies of Arid Zones and Dry Lands in Syria, and Centro Agronómico Tropical de Investigación y Enseñanza in Costa Rica have agreed to collaborate with IBSNAT. Another regional agricultural research center that has expressed interest in joining IBSNAT is the Institut de Recherche Agronomique et Zootechnique (IRAZ) in Burundi, which is also a member of the Commission Economique des Pays du Grand Lac (CEPGL), an organization serving Burundi, Rwanda, and Zaire. At the request of U.S. Agency for International Development, IBSNAT is also exploring the possibility of establishing the Caribbean Benchmark Sites Network for Agrotechnology Transfer (CARIBSNAT).

In addition to regional networks, most national programs have more than one benchmark site conducting IBSNAT-type experiments. For example, Venezuela has IBSNAT experiments in six of its major agroecological zones. Experiments conducted in regional and national networks are designed to serve two purposes.

A) First, they are designed to test and validate simulation models in a wide array of environments; and
B) Second, they generate the skill and confidence needed by users to apply systems-based research and simulation techniques for making adjustments in agricultural programs.

IBSNAT's major role is to ensure that research conducted in regional and national networks retains its global character. Further, it should encourage researchers to calibrate global simulation models, rather than country or region specific models. In the final analysis, the sharing of agrotechnology on an international scale is possible only through simulation models that predict global results. If the immense quantity of new technologies and cultivars that are currently being developed in national, regional, and international agricultural research centers is to be shared among all users, the simulation models must be able to predict the performance of crops, products, and practices in the widest possible range of user conditions.

Training Workshops

In December 1984, IBSNAT held a workshop on "Systems Analysis and Simulation of Crop Growth for Agrotechnology Transfer." The main purpose of that workshop was to introduce IBSNAT collaborators to the concepts of systems approach for crop growth simulation, and to provide participants with hands-on experience in operating the crop models on microcomputers, using the Data Base Management System. Workshop participants provided helpful comments and suggestions to improve the system. Minimum data set collection for modeling experiments were discussed, along with the application of models for research and agrotechnology transfer.

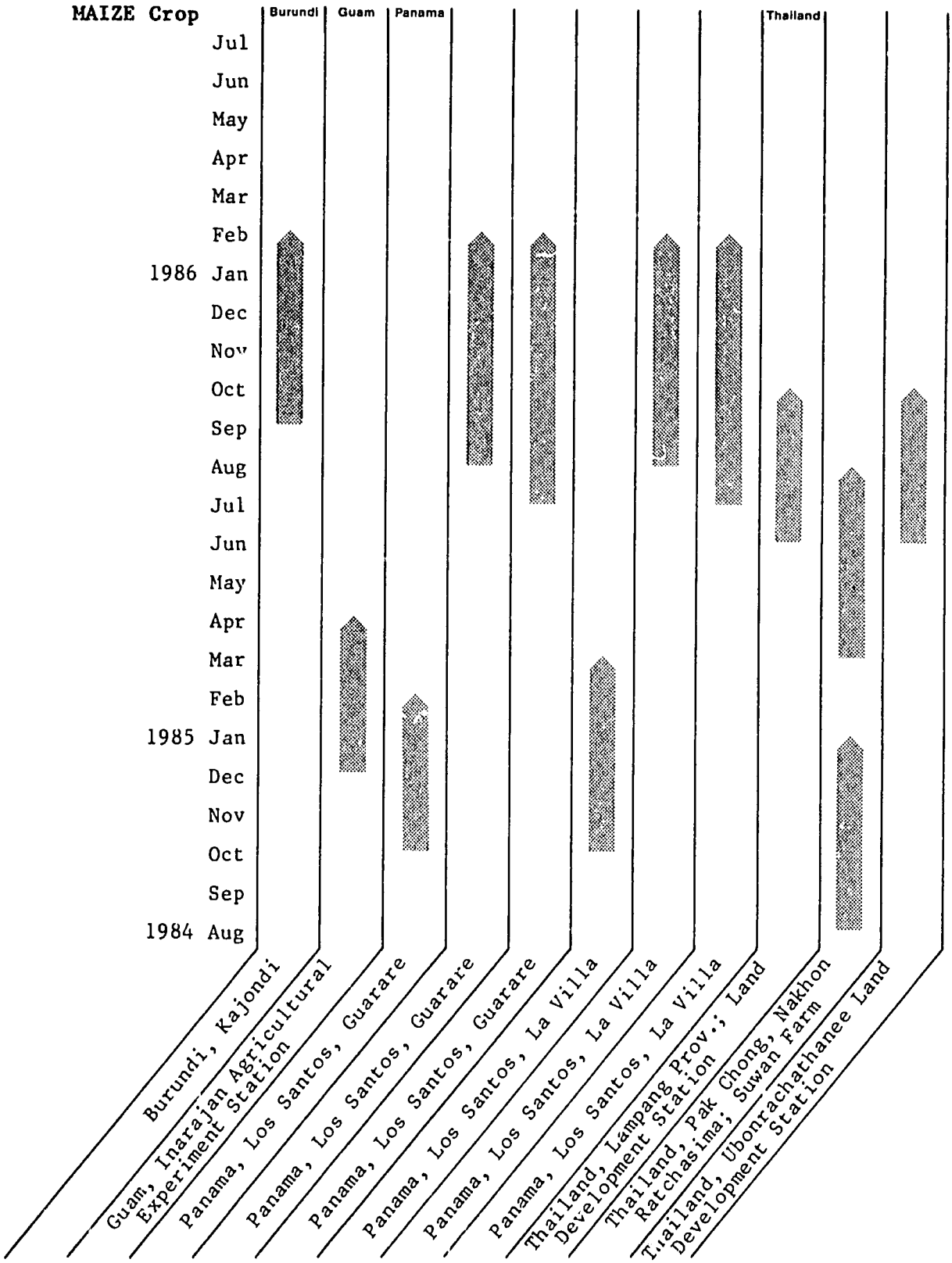
The practical sessions at the workshop provided an excellent way to demonstrate the CERES Wheat and Maize Models, and the SOYGRO Crop Model to participants, as well as familiarize them with the types of data inputs (soil, crop, and weather parameters) that are necessary to run model simulations. The experience of manipulating data sets and successfully executing programs on the microcomputer contributed towards building confidence in collaborators, and creating interest among participants for future model work.

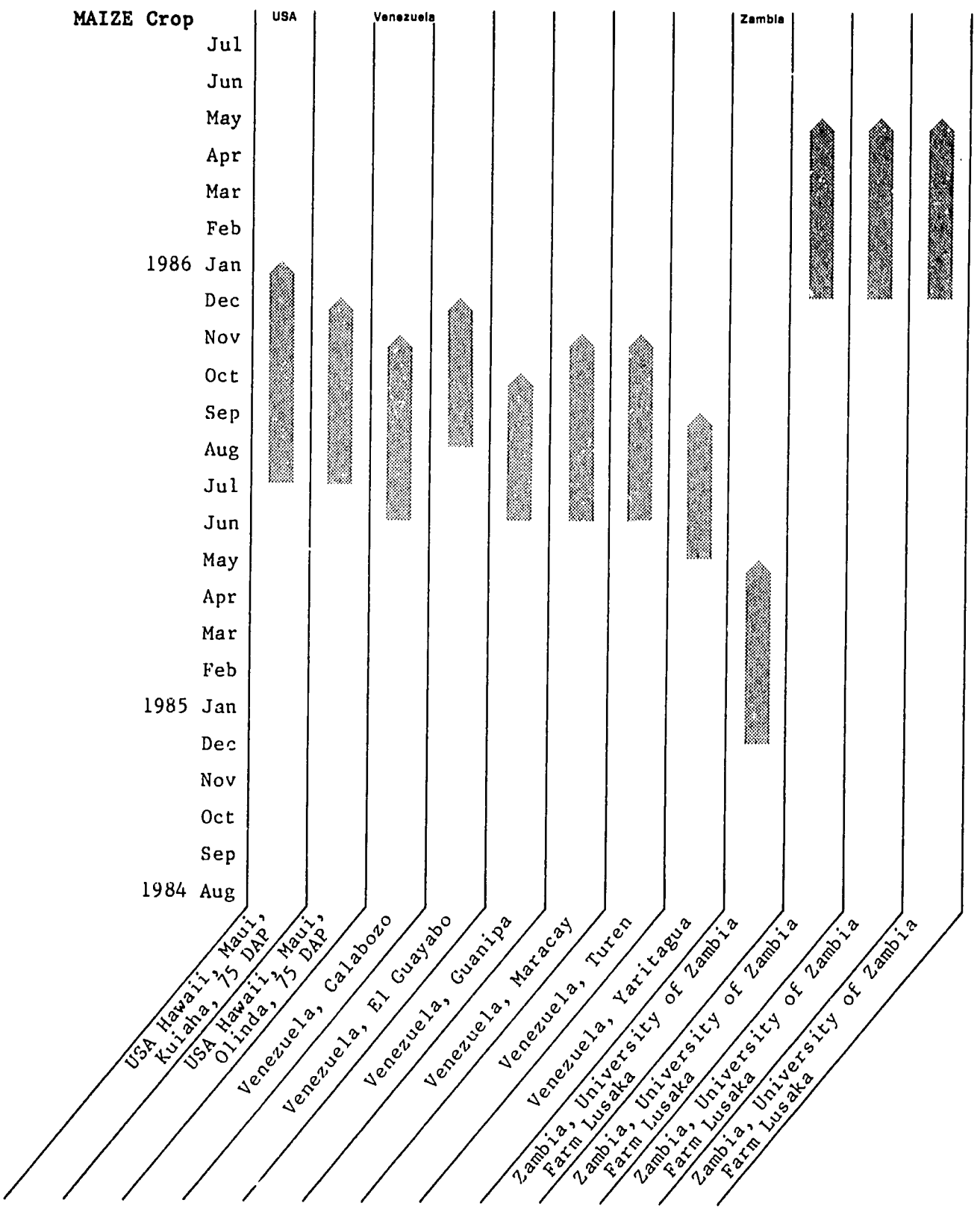
A second IBSNAT training workshop to be held in Amman, Jordan in November 1985 will focus on wheat and maize. The IBSNAT Project will cosponsor this second workshop, which will be hosted by the University of Jordan, in collaboration with the Arab Center for the Studies of Arid Zones and Dry Lands (ASCAD) and the USAID Mission in Amman.

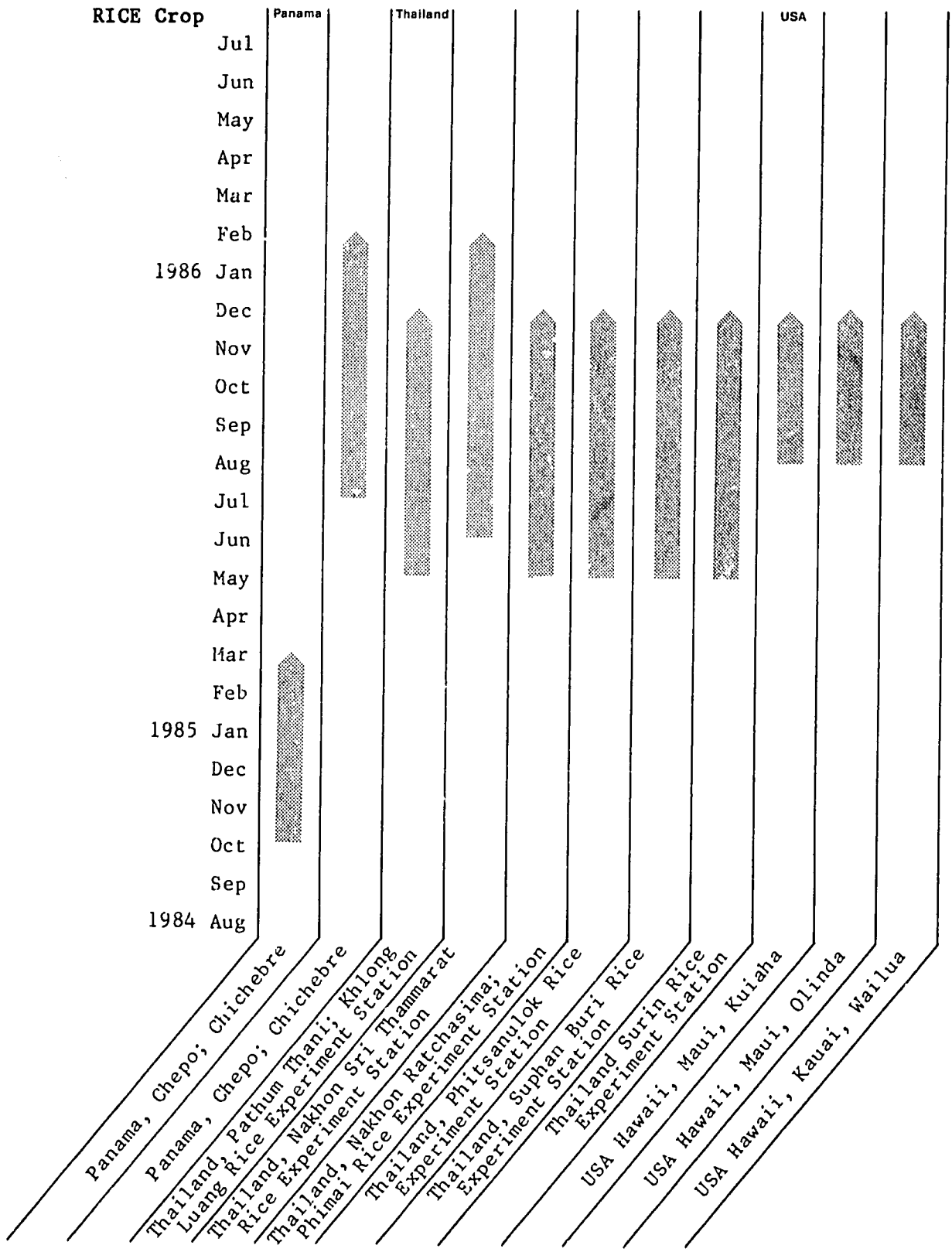
In June 1986, there will be a workshop to discuss the rice model. The Malaysian Agricultural Research and Development Institute (MARDI) has invited IBSNAT to plan the rice workshop in Malaysia. Preliminary planning meetings are scheduled to further develop the program and to identify the participants.

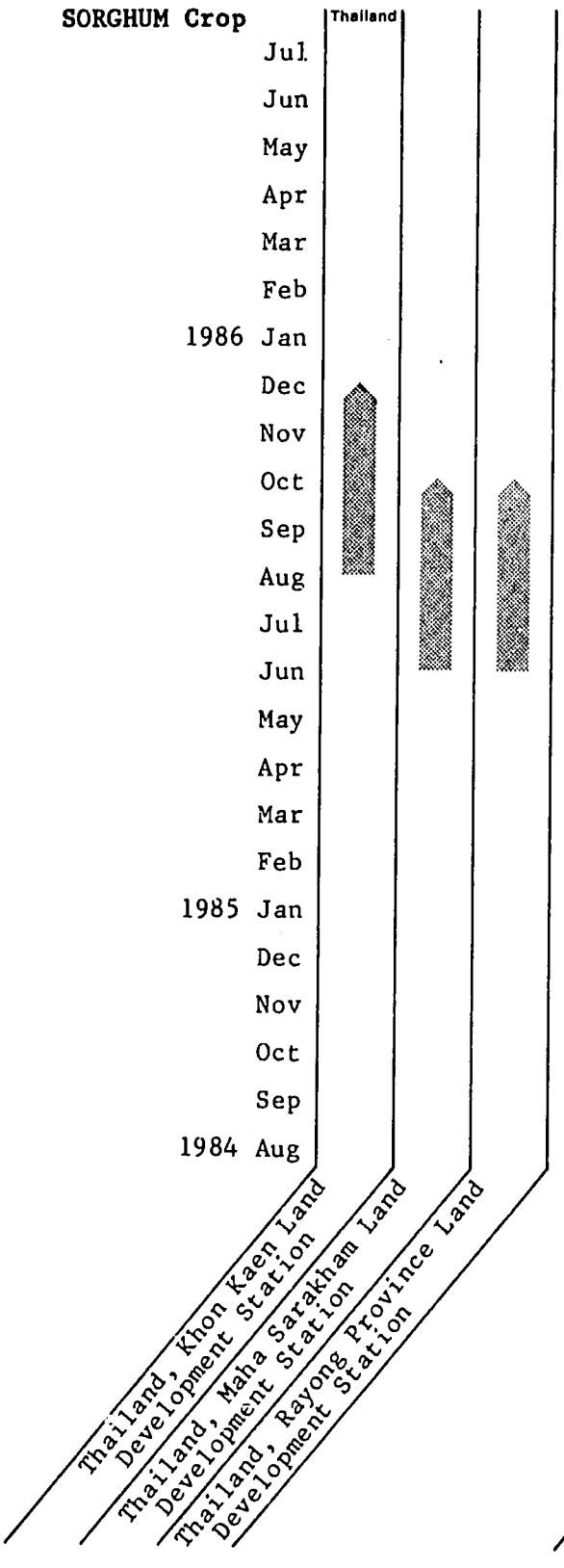
Participants of the 1984 workshop on "Systems Analysis and Simulation of Crop Growth for Agrotechnology Transfer" held at the Instituto Internacional de Estudios Avanzados in Caracas, Venezuela.

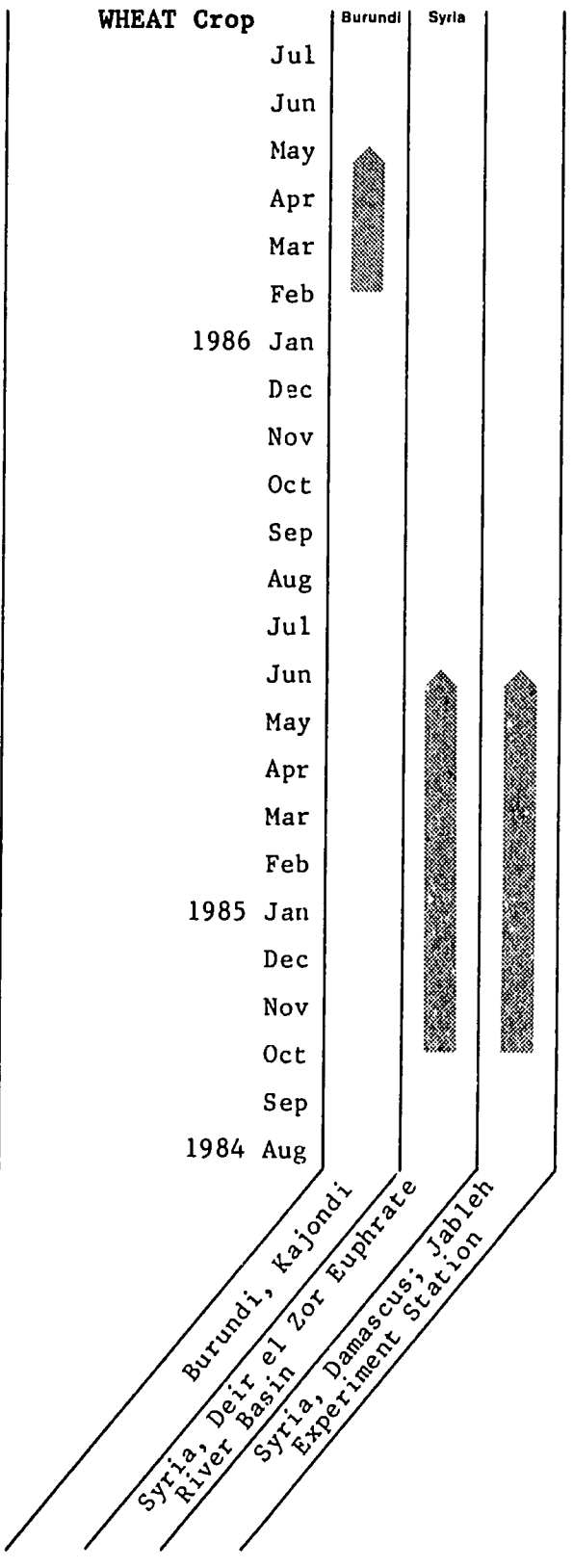
IBSNAT's Crop Planting Schedules

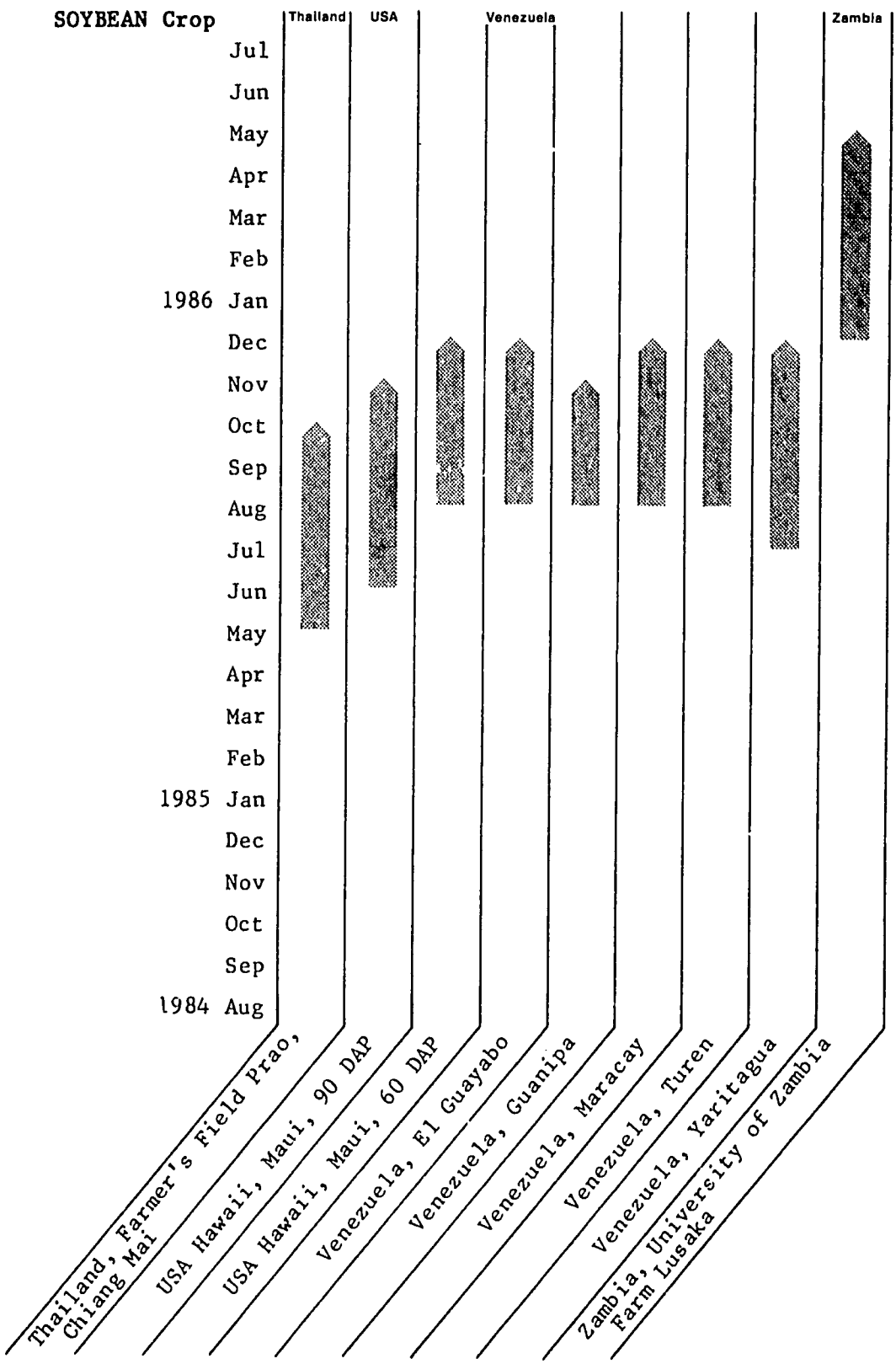


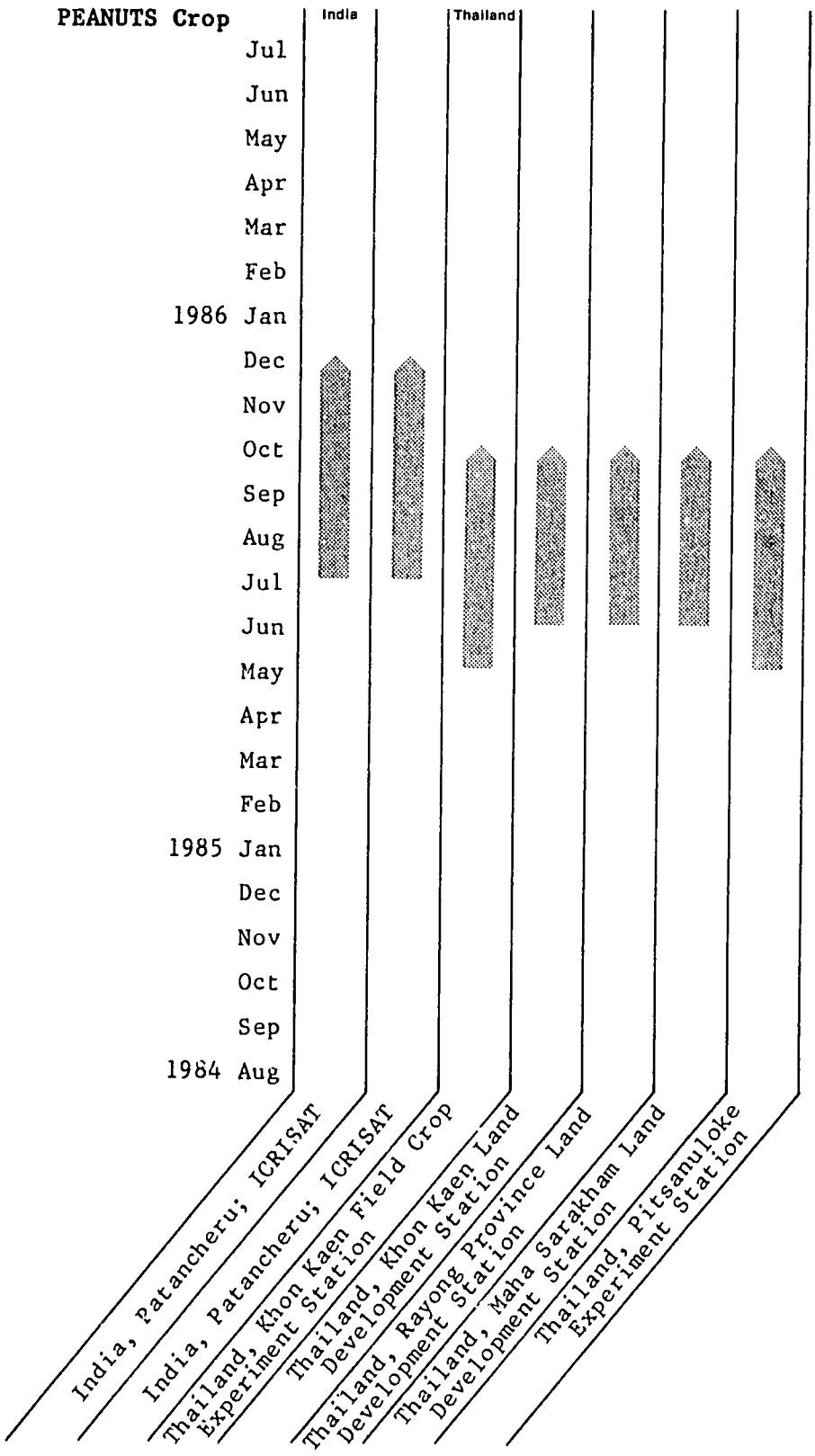

MAIZE Crop
USA
Venezuela
Zambia
Jul
Jun
May
Apr
Mar
Feb
1986 Jan
Dec
Nov
Oct
Sep
Aug
Jul
Jun
May
Apr
Mar
Feb
1985 Jan
Dec
Nov
Oct
Sep
1984 Aug
USA Hawaii, Maui, Kuiaha, 75 DAP
USA Hawaii, Maui, Olinda, 75 DAP
Venezuela, Calabozo
Venezuela, El Guayabo
Venezuela, Guanipa
Venezuela, Maracay
Venezuela, Turen
Venezuela, Yaritagua
Zambia, University of Zambia Farm Lusaka
Zambia, University of Zambia Farm Lusaka
Zambia, University of Zambia Farm Lusaka
Zambia, University of Zambia Farm Lusaka

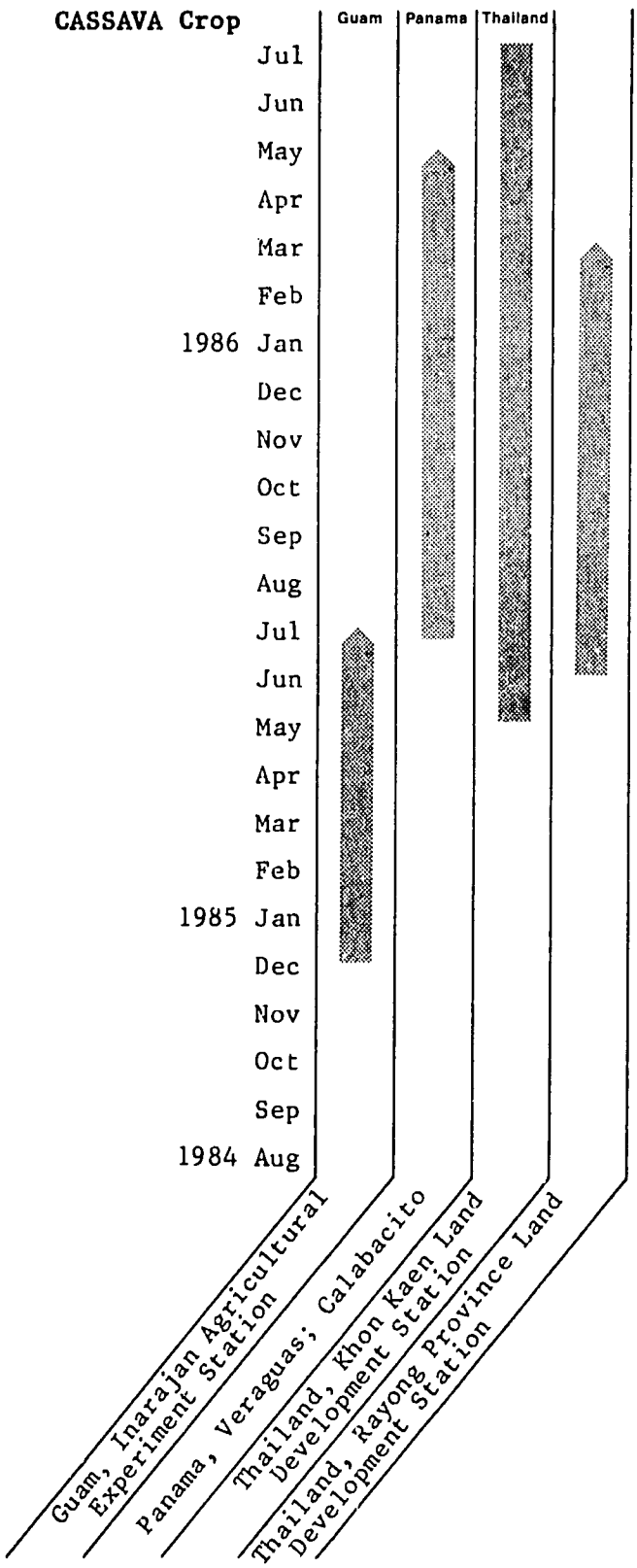

RICE Crop
Panama
Thailand
USA
Jul
Jun
May
Apr
Mar
Feb
1986 Jan
Dec
Nov
Oct
Sep
Aug
Jul
Jun
May
Apr
Mar
Feb
1985 Jan
Dec
Nov
Oct
Sep
1984 Aug
Panama, Chepo; Chichebre
Panama, Chepo; Chichebre
Thailand, Pathum Thani; Khlong Luang Rice Experiment Station
Thailand, Nakhon Sri Thammarat Rice Experiment Station
Thailand, Nakhon Ratchasima; Phimai Rice Experiment Station
Thailand, Phitsanulok Rice Experiment Station
Thailand, Suphan Buri Rice Experiment Station
Thailand Surin Rice Experiment Station
USA Hawaii, Maui, Kuiaha
USA Hawaii, Maui, Olinda
USA Hawaii, Kauai, Wailua

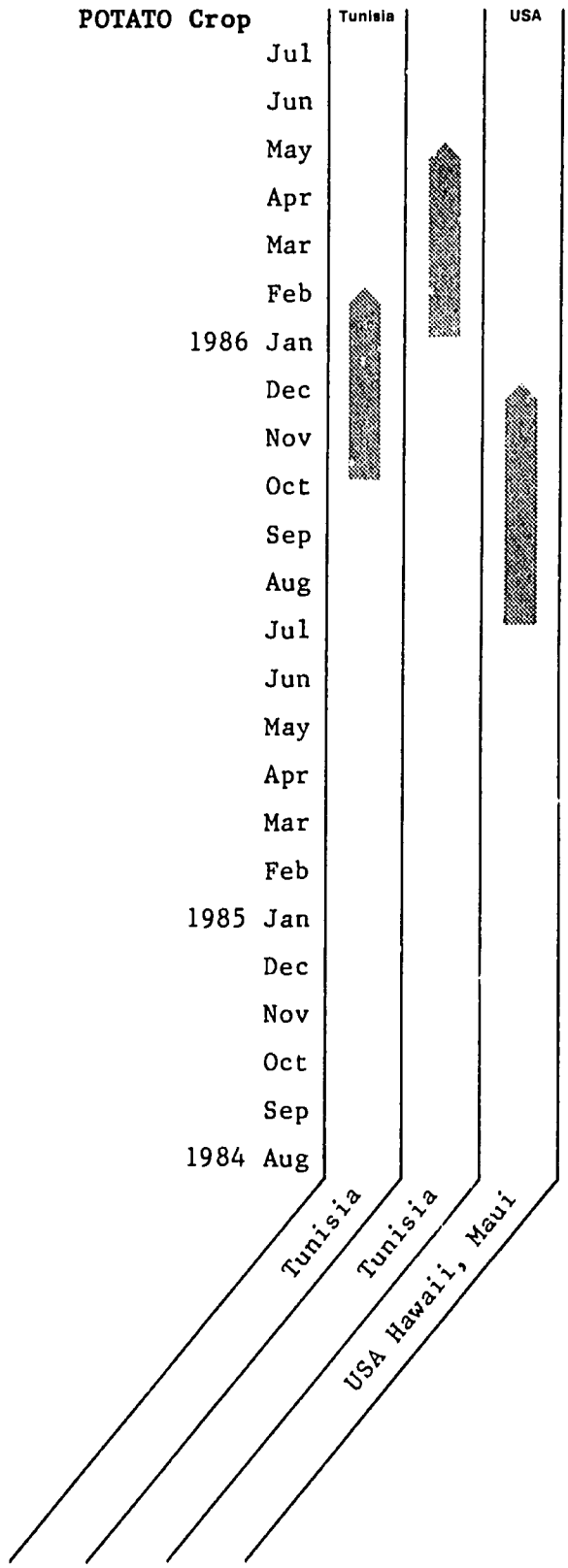

SORGHUM Crop
Thailand
Jul
Jun
May
Apr
Mar
Feb
1986 Jan
Dec
Nov
Oct
Sep
Aug
Jul
Jun
May
Apr
Mar
Feb
1985 Jan
Dec
Nov
Oct
Sep
1984 Aug
Thailand, Khon Kaen Land Development Station
Thailand, Maha Sarakham Land Development Station
Thailand, Rayong Province Land Development Station


WHEAT Crop
Burundi
Syria
Jul
Jun
May
Apr
Mar
Feb
1986 Jan
Dec
Nov
Oct
Sep
Aug
Jul
Jun
May
Apr
Mar
Feb
1985 Jan
Dec
Nov
Oct
Sep
1984 Aug
Burundi, Kajondi
Syria, Deir el Zor Euphrate River Basin
Syria, Damascus; Jableh Experiment Station


SOYBEAN Crop
Thailand
USA
Venezuela
Zambia
Jul
Jun
May
Apr
Mar
Feb
1986 Jan
Dec
Nov
Oct
Sep
Aug
Jul
Jun
May
Apr
Mar
Feb
1985 Jan
Dec
Nov
Oct
Sep
1984 Aug
Thailand, Farmer's Field Prao, Chiang Mai
USA Hawaii, Maui, 90 DAP
USA Hawaii, Maui, 60 DAP
Venezuela, El Guayabo
Venezuela, Guanipa
Venezuela, Maracay
Venezuela, Turen
Venezuela, Yaritagua
Zambia, University of Zambia Farm Lusaka


PEANUTS Crop
India
Thailand
Jul
Jun
May
Apr
Mar
Feb
1986 Jan
Dec
Nov
Oct
Sep
Aug
Jul
Jun
May
Apr
Mar
Feb
1985 Jan
Dec
Nov
Oct
Sep
1984 Aug
India, Patancheru; ICRISAT
India, Patancheru; ICRISAT
Thailand, Khon Kaen Field Crop Experiment Station
Thailand, Khon Kaen Land Development Station
Thailand, Rayong Province Land Development Station
Thailand, Maha Sarakham Land Development Station
Thailand, Pitsanuloke Experiment Station


CASSAVA Crop
Guam
Panama
Thailand
Jul
Jun
May
Apr
Mar
Feb
1986 Jan
Dec
Nov
Oct
Sep
Aug
Jul
Jun
May
Apr
Mar
Feb
1985 Jan
Dec
Nov
Oct
Sep
1984 Aug
Guam, Inarajan Agricultural Experiment Station
Panama, Veraguas; Calabacito
Thailand, Khon Kaen Land Development Station
Thailand, Rayong Province Land Development Station


POTATO Crop
Tunisia
USA
Jul
Jun
May
Apr
Mar
Feb
1986 Jan
Dec
Nov
Oct
Sep
Aug
Jul
Jun
May
Apr
Mar
Feb
1985 Jan
Dec
Nov
Oct
Sep
1984 Aug
Tunisia
Tunisia
USA Hawaii, Maui

APPENDIX B

Participants at IBSNAT Meetings

The "International Symposium on Minimum Data Sets for Agrotechnology Transfer" was held in Hyderabad, India, 20–26 March 1983. The following attendees participated.

Countries	*Participants*
Australia	Henry A. Nix
Brazil	Fernando L. Garagorry
	Manoel Abilio Queiroz
Burundi, Republic of	Clement Mathieu
Cameroon	J. P. Eckebil
	Simon N. Lyonga
Colombia	James H. Cock
Costa Rica	Julio M. Henao
Fiji	David M. Leslie
France	Daniel Wallach
Guam	R. Muniappan
India	J. C. Bhattacharjee
	J. R. Burford
	S. B. Deshpande
	Samir A. El-Swaify
	R. D. Ghodake
	Gamini Gunasekera
	A. K. S. Huda
	Vrinda Kumble
	R. J. Landey
	Murari Singh
	Sardar Singh
	Ronald B. Stryker
	Leslie D. Swindale
	Mahesh Upadhya
	S. M. Virmani
Italy	Amir Kassam
Malaysia	Boon Lian Kho
The Netherlands	W. G. Sombroek
Pakistan	Aurangzeb R. Khan
	Arthur J. ("Bud") McGinnis
Panamá	Jorge L. Jonas
Philippines	Crisanto R. Escaño
	Peter vander Zaag
Puerto Rico	Friedrich H. Beinroth
Syria	Abdallah Matar
	Ahmed Osman
Thailand	Samarn Panichapong
USA, Florida	James W. Jones
USA, Hawaii	Hariharan Eswaran
	Tung Liang
	James A. Silva
	Gordon Y. Tsuji
	Goro Uehara
	Russell S. Yost
USA, Missouri	Clarence Sakamoto
USA, New York	Foster B. Cady
	Elmer E. Ewing
USA, Texas	Frank G. Calhoun
	Paul T. Dyke
	Douglas C. Godwin
	C. Allan Jones
	Jimmy R. Williams
USA, Utah	Bert D. Tanner
USA, Washington	George T. Cox
USA, Washington, D.C.	Richard W. Arnold
	Tejpal S. Gill
Venezuela	Juan A. Comerma
West Germany	Halo Lueken

A symposium on the "Collaborative Research Networking for Agrotechnology Transfer: Experimental Designs and Collection of the Minimum Data Set" was held in Wailea, Maui, Hawaii, 13–17 August 1984. The following IBSNAT collaborators participated.

Countries	*Participants*
Australia	Douglas C. Godwin
	Henry A. Nix
	Peter J. Sands
Burundi, Republic of	Salvator Kaburungu
	Clement Mathieu
Cameroon	Emmanuel A. Atayi
Canada	L. Anthony Hunt
China, Republic of	Tzo-Chuan Juang
Costa Rica	Marciano Rodriguez
Fiji	Pram Sivan
France	Daniel Wallach
Guam	Jose A. Cruz
	Thao Khamoui
	R. Muniappan
	Anastacio L. Palafox
	Chu-tak Tseng
Guinea	Laye Kourouma
Indonesia	M. Sudjadi
	Karmatias
	Eko Legowo
Jordan	Anwar M. Battikhi
Lesotho	P. Matt Cauley
	Rose Matela
Malaysia	Bin Abu Bakar Ismail
New Zealand	J. Barry Dent
	David M. Leslie
	Bruce B. Trangmar
Panama	Jorge L. Jonas
Pakistan	Aurangzeb R. Khan
	Arthur J. ("Bud") McGinnis

Philippines	Crisanto R. Escaño
	Richard A. Morris
	Roel Oldeman
Puerto Rico	Friedrich H. Beinroth
Senegal	Jean-Pierre N'diaye
Syria	Wolfgang Goebel
	Ahmed Osman
Thailand	Chayong Nammuang
	Samarn Panichapong
USA, Florida	James W. Jones
	Wayne Mishoe
USA, Hawaii	Harold L. Baker
	Duane Bartholomew
	Bernardino Cagauan, Jr.
	Clement Chan
	Patrick C. Ching
	Anders P. Daniels
	Robert Gavenda
	Ronald Guyton
	Jake Halliday
	Clark Hashimoto
	Ted M. Hori
	Haruyoshi ("Ike") Ikawa
	Noel P. Kefford
	Akram Khan
	Ping Sun Leung
	Tung Liang
	John Powley
	John Roecklein
	Dan Shigeta
	James A. Silva
	Upendra Singh
	Gordon Y. Tsuji
	Goro Uehara
	Sheldon A. Whitney
	Russell S. Yost
USA, Louisiana	Wayne H. Hudnall
USA, Nebraska	Steven C. Holzhey
USA, New Jersey	Grant F. Walton
USA, New York	Foster B. Cady
	Elmer E. Ewing
	Luis A. Manrique
USA, Oklahoma	Arlin Nicks
USA, Texas	Paul T. Dyke
	C. Allan Jones
	Joe T. Ritchie
USA, Utah	George H. Hargreaves
USA, Washington, D.C.	Richard W. Arnold
	Nyle C. Brady
	Hariharan Eswaran
	Tejpal S. Gill
Venezuela	William C. Avilan
	Juan A. Comerma
Zambia	Vernon R. N. Chinene

A workshop on the "Systems Analysis and Simulation of Crop Growth for Agrotechnology Transfer," held in Caracas, Venezuela, 3–14 December 1984. The following attendees participated.

Countries	*Participants*
Australia	Henry A. Nix
Bangladesh	Sikder Muhammed Saheed
Costa Rica	José Arze
Guam	Chu-tak Tseng
India	Piara Singh
Indonesia	I Putu G. Widjaja-Adhi
Jordan	Nasri Ibrahim Al-Haddad
Malaysia	Aminuddin Bin Yusoff
Pakistan	Muhammad Mazhar I. Nizami
Panamá	Jorge L. Jonas
Philippines	Lolita N. Ragus
Thailand	M. L. Chakranopakhun Tongyai
USA, Florida	James W. Jones
USA, Hawaii	Bernardino Cagauan, Jr.
	Clement Chan
	Patrick C. Ching
USA, Michigan	Joe T. Ritchie
USA, Texas	C. Allan Jones
Venezuela	Ignacio Avila
	William Avilan
	Luis Bascones
	Dunja Beg
	Francisco Blanco
	Francisco Benito Blanco
	Lelys I. Bravo De Guenni
	Orlando Guenni
	Jesús Paraqueima
	Aníbal Rosales
	Stalin Torres
	Juan Valdez
	Leopoldo Villegas
Zambia	Obed I. Lungu

APPENDIX C

Bibliography of IBSNAT Project Publications

Publications

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Jones, C. A., ed. 1984. Experimental Design and Data Collection Procedures for IBSNAT. IBSNAT Technical Report 1. Dept. Agron. Soil Sci., College of Trop. Agr. and Human Resources, Univ. Hawaii.

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APPENDIX D

Institution Acronyms in Progress Report

Code	Name
AARD	Agency for Agricultural Research and Development (Jakarta, Indonesia)
ABSNAT	ASEAN Benchmark Sites Network for Agrotechnology Transfer
ACSAD	Arab Center for Studies of Arid Zones and Dry Lands (Damascus, Syria)
AID/S&T/ AGR/RNR	Agency for International Development, Bureau for Science and Technology, Office of Agriculture, Renewable Natural Resources (Washington, D.C., USA)
ARS	Agricultural Research Service (Temple, Texas, USA)
ASEAN	Association of Southeast Asian Nations
AVRDC	Asian Vegetable Research and Development Center (Taiwan, Republic of China)
CARIBSNAT	Caribbean Benchmark Sites Network for Agrotechnology Transfer
CATIE	Centro Agronómico Tropical de Investigación y Enseñanza (Turrialba, Costa Rica)
CENIAP	Centro Nacional de Investigaciones Agropecuárias (Maracay, Venezuela)
CEPGL	Commission Economique des Pays du Grande Lac
CIAT	Centro Internacional de Agricultura Tropical (Cali, Colombia)
CIP	Centro Internacional de la Papa [=International Potato Center] (Lima, Peru)
COFAF	Committee on Food, Agriculture and Forestry (ASEAN)
CSIRO	Commonwealth Scientific and Industrial Research Organization (Brisbane, Australia)
CSR	Centre for Soil Research (Bogor, Indonesia)
DSIR	Department of Scientific and Industrial Research (Lower Hutt, New Zealand)
FAO	Food and Agriculture Organization (United Nations, Rome, Italy)
FFTC/ASPAC	Food and Fertilizer Technology Center for the Asian and Pacific Region (Taipei, Taiwan, Republic of China)
FONAIAP	Fondo Nacional de Investigaciones Agropecuárias (Caracas, Venezuela)
IBSNAT	International Benchmark Sites Network for Agrotechnology Transfer
ICARDA	International Center for Agricultural Research in the Dry Areas (Aleppo, Syria)
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics (Hyderabad, India)
IDIAP	Instituto de Investigación Agropecuária de Panamá [=National Research Institute of Panamá] (Panamá)
IFDC	International Fertilizer Development Center (Muscle Shoals, Alabama, USA)
INRA	Institut National de la Recherche Agronomique (Toulouse, France)
IRA	Institut de la Recherche Agronomique (Yaounde, Cameroon)
IRAZ	Institut de Recherche Agronomique et Zootechnique (Burundi)
MARDI	Malaysian Agricultural Research and Development Institute (Malaysia)
MPI	Ministry of Primary Industries (Suva, Fiji)
NSSL	National Soil Survey Laboratory (SCS) (Lincoln, Nebraska)
OBSNAT	Oceania Benchmark Sites Network for Agrotechnology Transfer
PARC	Pakistan Agricultural Research Council (Islamabad, Pakistan)
PCARRD	Philippine Council for Agriculture and Resources Research and Development (Manila, Philippines)
RCUH	Research Corporation of the University of Hawaii (Honolulu, Hawaii, USA)
SCS	Soil Conservation Service
SMSS	Soil Management Support Services (Washington, D.C., USA)
USAID	United States Agency for International Development
USDA/ARS	United States Department of Agriculture, Agricultural Research Service
USDA/SCS	United States Department of Agriculture, Soil Conservation Service (Washington, D.C., USA)