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WATER MANAGEMENT RESEARCH
IN ARID AND SUB-HUMID LANDS
OF LESS DEVELOPED COUNTRIES

Contract AID/csd-2167

Third Annual Progress Report

November 1, 1970 to October 31, 1971

to

The United States Agency
for International Development

prepared by

The Department of Agricultural
and Irrigation Engineering

Utah State University
Logan, Utah 84321
USA

GENERAL BACKGROUND

Water managers make decisions based on the information which they have available. Information used for water management decisions in our country is not always applicable in another because of differences in climate, soil, topography, availability of machinery, labor costs, markets and cultural differences.

The study and evaluation of these factors as they relate to water management for food production increase in lesser developed countries is the essence of USU's on-farm water management research contract.

Water management research is particularly urgent in these nations today because many governments and international lending institutions see water resource development as one of the most effective ways of increasing agricultural production and employment. It is possible to increase agricultural land values a thousandfold through proper management of water resources.

PROJECT OBJECTIVES

As stated in the contract, "The general objective of this research is to increase food production in the arid and sub-humid lands of the less developed countries through the improvement of water management practices and the integration of those with other good management and cultural procedures. The research under this contract will be aimed at water management problems in the semi-arid lands of the Latin American region but will be applicable in principle to similar conditions in other regions. This improvement of water management practices is necessary to obtain maximum economic returns from limited water resources and such inputs as improved seeds, increased use of fertilizers and pesticides, and supporting institutional structure."

SPECIFIC OBJECTIVES

The specific research studies will be selected to meet the high priority needs of the Latin American area and of Venezuela. These studies will include but not be limited to:

1. The development of knowledge and data on how best to conserve and utilize water falling on the land as rain and the most efficient means of supplementing needed soil moisture by limited amounts of irrigation water.

2. The development of knowledge and data that can be used for the economic on-farm design and construction of conveyance and delivery systems including structures for control and measurement of irrigation water.

3. The development of surface and sub-surface drainage systems to eliminate the hazards resulting from surface flooding and high water tables.

4. The identification of important factors affecting the degree of levelling of the various soils in the major climatic zones and the relationship of these factors to erosion, water infiltration, and good land use and cropping practices.

5. The development of methods of water application, including time and amounts, which are suitable and efficient for different soils of varying physical properties (water-holding capacities, intake rates, etc.) with major crops.

6. The integration of these water-use factors into a productive cropping system consistent with farm size and available farming practices.

7. Where soil salinity and exchangeable sodium are problems, studies will include soil amendments, soil and water management procedures and use of salt-tolerant crops.

CONTINUED RELEVANCE OF OBJECTIVES

Since the date of signing of the contract in June 1968, several developments have caused some modifications in the orientation and emphasis of the work.

It is evident from the wording of the contract and from verbal and written communications with AID/Washington that USU's research activities must be carried out by mutual agreement with host country agricultural research agencies and AID missions.

Subsequent to the drawing up of the original contract, AID mission activities in Venezuela were phased out. Except for the water requirements component, contract activities were accordingly transferred to other countries.

Among the above mentioned specific objectives, the interest level in the host country agencies and AID missions varied considerably.

USU developed during the first eighteen months of the contract plans of work, and these were mutually agreed to by appropriate host country agencies and AID missions. The first plan was verbally arranged between the Chilean Ministry of Agriculture, AID/Chile and USU. It emphasized water-fertilizer interaction on corn to be carried out with Department of Agriculture researchers in the Aconcagua Valley near the city of Los Andes. Subsequently other written agreements were arranged with the governments and AID missions of Brazil, Colombia, Ecuador and El Salvador. These appear as Appendices B through F of the Second Annual Progress Report. Perusal of these agreements will indicate that no direct reference is made to the first specific objective as listed above.

It is of importance to those reviewing this contract to understand that USU can involve itself in only those activities which the AID missions and host agencies agree are important to the current needs of the country. This is the overriding constraint. Even the work being carried out primarily at Utah State University is supporting the agreed upon field activities.

A component not directly referred to in the contract but which AID, through its Dr. Douglas Caton specifically requested be included, is the economic evaluation of the impact of irrigation and irrigation research in the Latin American countries. This was therefore added to the original work plan and is being vigorously carried out.

The original contract objectives are still relevant. All are not receiving equal emphasis as will become evident in this report.

ACCOMPLISHMENTS TO DATE

It is assumed that the reader has access to the following documents:

"Water Management Research in Arid and Sub-Humid Lands of Less Developed Countries"

- First Annual Progress Report
- Second Annual Progress Report
- Plan of Work - April 1, 1970 - March 31, 1971

Accomplishments will be discussed by programs as listed on page 2 of the Second Annual Progress Report.

PO1: To determine the irrigation interactions with crop varieties, plant populations and fertilizers for optimum production of crops in the wet-dry areas of Latin America.

CHILE

Professor Don C. Kidman arrived in the fall of 1969 on a short-term assignment to study the possibilities of working on water management research. Previous discussions had indicated the likelyhood that water-fertilizer interaction experiments could be carried out in the Aconcagua Valley north of Santiago.

His evaluation of the situation was positive. Work was commenced immediately and in March and April 1970 plots on six research areas were harvested. This work was reported by Rodrigo Reyes Mege as an undergraduate thesis in connection with his agronomic studies at the Catholic University of Valparaiso entitled, "Interacciones de Riego en Variedades de Cultivo Poblaciones de Plantas y Fertilizantes." These studies included variety, nitrogen, irrigation andplant population components.

The results of the two-variety comparisons indicated the variety Tracy 133 to be a consistently better producer than the variety Tracy 90 at 60,000 plants per hectare. At 90,000 they were both higher but approximately equal to each other.

Significant responses to nitrogen and to the higher water application rates were noted.

For the 1970-71 crop year similar plots were laid out, the major changes being the elimination of a variety component and the adding of a seedbed preparation component. The corn variety tested was a

Chilean hybrid, MA7. This was selected by the Ministry of Agriculture as a result of previous testing.

Several rather surprising results were recorded. Whereas the previous year's work indicated optimum plant populations at 80 to 90 thousand plants per hectare, the average yields on the MA7 variety showed a decrease over the full range of populations tested, i.e., from 60,000 to 125,000 plants per hectare.

On the El Castillo and Candoroma plots there was no significant response to nitrogen variation, indicating a high carryover of nitrogen in the soil. There was little statistical evidence of a positive effect of careful soil preparation prior to planting as compared to traditional methods. In all cases plant yields increased with increased water application rates. Thus, there were no meaningful interactions between the variables.

The variety tested is considered by the Chilean government to have good potential for this region of Chile, so the 1971-72 crop year has been planned using this variety again plus the Tracy varieties used in the 1969-70 crop year. New land has been selected where ambient nitrogen is low and lower plant population ranges have been selected.

It is anticipated that with these modifications, interaction between the variables will become evident.

We are hopeful that we will be permitted to carry on through one more crop year, i.e., 1972-73, in order to substantiate the results of the current research. The results of the 1970-71 and 1971-72 crop years will be published together. A progress report is included as Appendix E.

Other Activities and Observations Related to the Chilean PO1 Program

In order to help develop competance among their Chilean research counterparts, Professor Kern Stutler has given them short courses in the fundamentals of water measurement and application and in land levelling and surface preparation. This has resulted in more effective counterpart research assistance.

We have noted with considerable satisfaction an excellent rapport which has developed between the USU researchers and their Chilean counterparts. The whole operation has been an excellent example of a team approach to research.

On the four communal farms where plots are located (asentamientos), cultural practices introduced on the plots are almost immediately adopted on the remainder of the farms. This resulted last year in an increase of about 96% in corn yield on these farms. Projecting this increase over the 2410 hectares of corn planted in the Aconcagua Valley in 1971, a new increase in farm income of 9,358,000 escudos, or US $280 per hectare is feasible at a production rate of 88 quintales per hectare and a return of 100.00 escudos per quintal.

The direct, daily involvement of USU's two researchers, Don Carlos Kidman and Kern Stutler with technicians of the Chilean Agriculture Research Institute and the Agriculture and Livestock Service is developing a competance which, because of the nationwide involvement of these institutes will have an excellent chance of extending into many other corn producing areas throughout the country.

USU Short Term Assistance

Because of the political necessity to maintain a low American profile in the country, visits by USU specialists were restricted to two. Byron C. Palmer, Field Director of the program, visited Chile in April, and Dr. David James, an agronomist specializing in experimental plot layout and data analysis, visited Chile in August. He assisted the field staff in the evaluation of field data and the design of the experiments for the 1971-72 crop year.

Future Activities

The results of the crop now in the ground will be analyzed in May of 1972 and a report written. Further activities beyond this period are contingent on a direct government request to AID for a continuation and their response.

EL SALVADOR

Water-fertilizer interaction experiments on corn in El Salvador were carried out during the year in cooperation with the research arms of the Ministry of Agriculture at their demonstration farm "La Granja" located in the Zapotitan Valley about an hour's drive from San Salvador.

No interactions were statistically demonstrable, but in this case the problem was a high water table which prohibited the stressing of the crops. In addition, a wide variation in soil type in the experimental plots masked significant fertilizer responses. However, the exercise did not dampen the enthusiasm of the researchers, and another area more suitable for this type of research has been selected by the Ministry. New plots will be planted in March of 1972. This year has been a good rehearsal. All the cultural practices were carried out so our researcher, Professor Richard E. Griffin, is assured of the logistical and counterpart support he needs to carry through on next year's experiments.

BRAZIL

Professors Norris Gilbert and Lloyd Austin arrived in Brazil at the end of March. Their primary tasks are to assist the Sao Francisco Development Agency---SUVALE---to establish irrigation experiments on three new agricultural research stations in the Sao Francisco Valley at Pirapora, Formoso and Barreiras. One component is to be water-fertilizer interaction. These are new stations where the main thrust during the six months since they arrived has been the building of pumping stations and canals, levelling the land, securing agricultural machinery, building office and storage buildings, securing seeds, planning and staking out research plots and installing surface drains, mainly at the Barreiras project.

An interesting item came to light after the arrival of USU staff. There is an agreement between SUVALE and IPEACO (Instituto de Pesquisas e Experimentacao Agropecuarias do Centro Oeste) for consultation and assistance to SUVALE's research activities by IPEACO. The latter is a government financed agricultural research agency with research stations and professional staff. The USU staff has spent considerable time in assisting these two agencies to identify areas of responsibility so that all of their available resources can be effectively focused on the development and operation of SUVALE's research stations.

Short Term Visits by USU Staff

Three visits were made. Byron Palmer arrived in Rio de Janeiro in April and spent a week reviewing with AID, SUVALE and the U.S. Bureau of Reclamation team the plan of work for the USU team.

Professor Rex Nielson, an agronomist, visited the research stations with the staff from August 8 to 27. His trip report in included as Appendix A in order to illustrate the types of problems with which field researchers have to deal.

COLOMBIA

Section C c(4) of the Colombian Memorandum of Understanding and Agreement specifies as part of the program..."To determine the irrigation interactions with crop varieties, plant populations, and fertilizers for optimum production of crops."

Doctor Thomas Fullerton, an agronomist formerly on the staff of the Nebraska mission to Colombia, was recruited and sent to Colombia in August. He has spent the two months of this reporting period establishing relationships with his counterparts in the Colombian Agricultural

Institute (ICA) and the Colombian Institute of Agrarian Reform (INCORA). ICA has two experimental stations on INCORA's Atlantico-3 project and one on their Magdalena-1 project on Colombia's north coast. Irrigation research was already underway, but no interaction experiments had been established yet. Dr. Fullerton and USU's other resident researcher, Dr. Edwin C. Olsen, are participating in land levelling and distribution canal design so that plot work can begin shortly after the new year.

PO2: To prepare and publish technical bulletins on evapotranspiration and water requirements for Latin America on a country and/or regional basis.

This program is supervised directly from Logan by Professor Jerald E. Christiansen. Working closely with him is George H. Hargreaves, a research engineer, and Richard W. Conn, a research technician.

The justification for this research activity lies in the fact that the consumptive use of water equations used for many years in the western United States rely primarily on measuring the monthly variations in sunlight and temperature. In the tropcs, where there is little variation in these parameters, other criteria become predominant. Appendix G in the Second Annual Progress Report, entitled "Irrigation Requirements in Latin American Countries," describes the effects of extraterrestrial radiation, mean temperature, mean humidity, wind velocity, sunshine, and elevation.

Professors Christiansen and Hargreaves have been working with Latin American hydrometeorological data for many years. Under this contract they are collecting and analyzing this data from Bolivia, Chile, Colombia, Ecuador, El Salvador, Guatamala, Honduras, Nicaragua, Panama and Venezuela.

Two reports have been prepared on Venezuela, two on Colombia, one on Honduras, one on Ecuador. Others are in preparation. In each case, considerable assistance has been provided by students at USU, usually nationals of the country whose data is being analyzed.

During the spring, Engineer Jose Yepez, Chief of Ecuador's Meteorological Service in its Ministry of Hydraulic Works, spent three months at USU analyzing the data from his country. Similarly, Engineer Fabio Carias from the Honduras Ministry of Agriculture analyzed under Christiansen and Hargreaves' supervision the data from his country.

Cartographers of the government of El Salvador have developed and printed monthly rainfall deficiency maps based on their data analyzed at USU. In the coming year reports will be prepared for the remaining countries listed. There is a likelyhood that Brazil will ask us to assist them in evaluating their data for the Sao Francisco Valley and recommend modifications in their hydrological research data collection program.

The significance of this program lies in its vastly improved ability to estimate crop water requirements in the tropics. Comparisons with traditional methods indicate frequent differences of over 50% when compared with the Christiansen-Hargreaves method.

With four or five foreign students working on theses directly related to crop water requirements, with hydrologists coming to Logan to work on their data, with a continual stream of data passing between Logan and hydrologists in the countries mentioned and with Christiansen and Hargreaves visiting these countries two or three times a year, there is a good dissemination of their research. Supporting this activity is research on specific crops being conducted in Ecuador by their Ministry of Hydraulic Works and in El Salvador by their Ministry of Agriculture. We are very interested in their lysimeter studies and have helped them set up their apparatus and trained their operators.

PO3: To determine more specifically the extent and nature of the drainage and salinity problems in Latin America and to find solutions to these problems, especially in the high water table areas.

COLOMBIA

Dr. Edwin C. Olsen, an irrigation and drainage engineer, arrived in Colombia in January 1971 to work on the north coast with ICA and INCORA primarily in drainage research. The area known as Atlantico-3 has a potentially serious drainage and salinity problem which could affect over 20,000 hectares of good farm land if the problem is left uncontrolled.

It is already showing up in a 400-hectare citrus grove. About 10% of the trees planted during the past five years have died, likely because of the high water table.

Dr. Olsen and his Colombian counterparts are vigorously carrying out the program specified in Appendix C and amplified in Appendix D of the Second Annual Progress Report.

Their work has been somewhat hampered by a tight budget in ICA and shipping delays in getting essential laboratory equipment into their project area. Even the 300 meters of perforated flexible plastic pipe essential to their drainage research had to be shipped in from the United States. However, Dr. Olsen and his counterparts are working well together. Several dozen piezometers are installed in the drainage research area, and during the coming year sufficient data should be generated to establish the necessary criteria to determine how to control the water table in the whole project.

EL SALVADOR

The Zapotitan Valley has a major drainage problem generated by high rainfall during the "winter", highly organic soils that are quite impermeable, flat slopes on the valley floor and artesian water pressure coming from the surrounding mountains.

Professor Griffin is assisting in the development of drainage criteria. The work is dealing primarily with the development of the most economic, effective cross-section and spacing of open main drains and the spacing and depth of buried perforated, plastic, flexible, lateral drains. An interesting additional component has been the study of the feasibility of using the drainage system during the dry summer months for sub-surface irrigation. Griffin's studies have shown that in the Zapotitan Valley this is not feasible, primarily because of the uneven texture of the soil, uniform water application is not possible. His report is being readied for publication.

The Ministry of Agriculture's research department has expressed interest in installing and evaluating mole drains. We have supplied them with plow designs based on the research currently underway at USU. It is anticipated that several acres of experimental drains will be installed during 1972.

<u>USU Campus Activity - Mole Drain Research</u>

One of the original constraints of the contract limited field activity for the first eighteen months to short-term visits. In order to get some useful activities underway during this interval, USU developed some linkages with one of its other Latin American programs known as its Inter American Center for the Integral Development of Land and Water Resources (CIDIAT) which had among its several activities a field plot research component at Guanare, Venezuela. Dr. Raymond Miller was the USU field researcher. He worked with counterparts from the Ministry of Public Works and the Ministry of Agriculture to develop irrigated field plots. One of their objectives was to find some economical method of getting rid of water on or near the surface of the ground as soon after the winter rains as possible in order to minimize the unproductive period when the land was drying prior to planting a new crop.

This initial linkage started us on mole drain research on campus. Soon after we got started AID/Venezuela began to phase out of that country, so the impetus to increase our involvement in the Guanare experiments through the AID contract died. However, during this period other agreements were being negotiated and the Colombian government, recognizing that they had similar problems in several areas, asked that a mole drain component be included in the plan of work for that country. El Salvador also requested collaboration on experimental mole drains.

This therefore provided the necessary impetus to press ahead on the on-campus work. Dr. Komain Unhanand and Dr. Bert Embry, together with graduate students developed eight different designs as they studied the shapes of double and single mole plows which offered the least resistance to the force required to pull them through the soil. Also studied was the effect of shape in maintaining an open tunnel through the soil.

Three Master's theses and a progress report have been generated. In addition, Dr. Embry, through two visits to Colombia and one to El Salvador, provided the plans and helped in the fabrication of mole plows for their research agencies.

Specific objectives of this research are:

1. To determine the effect of shape and size of the plows on power requirements.

2. To discover the best plow shape for maintaining an open mole tunnel.

3. To determine the types of soil that will support mole drains for a reasonable period of time.

4. To determine the relationship between soil moisture and tractor power requirements.

5. To evaluate the effectiveness of mole drains in reducing salinity in the soil.

6. To compare crop production on mole plowed plots with control plots.

These objectives are discussed in the reports.

PO4: The original sub-program---"To determine the effect of water management practices on crop yields by utilizing available water during the fall, winter and early spring seasons to fill the root zone soil moisture reservoir"---is getting underway in Brazil on the three research stations previously mentioned. Both the USU and counterpart staff have been concentrating their efforts on the physical resources as mentioned earlier. However, wet season crops are now planted, and one of the research components is designed to evaluate the effect of supplemental irrigation, if it is needed this year on crops planted to take advantage of the rainy season.

The other component of this sub-program, "to develop criteria for optimizing the use of available water by matching cropping patterns to the available supply," is being built into the Brazil plots and also the Colombian plots at Santa Lucia and Marconia. No results are available yet.

Results will be easier to get from Colombia than Brazil because the wet-dry cycles of Colombia's north coast are much more uniform than in the interior of north-east Brazil.

<u>PO5:</u> To assist SUVALE of Brazil in planning and implementing a program of research, training and demonstration in selected areas of the Sao Francisco River Basin.

In addition to references previously made to the Brazil activities, it is worthwhile to note that in order to carry out effective research, some specialized training of counterpart staff is often necessary. This has been specifically requested through the Memorandum of Understanding. This has not been interpreted as formal classroom lectures. Rather, the USU field staff and short-term professionals use every opportunity both in the SUVALE head offices in Rio and at the research farms to discover and use "teaching moments" to put across specific research concepts.

Further details of work accomplished during this reporting period in Brazil are included as Appendix B.

PO6: To assemble, evaluate and make available pertinent information relative to water rights and customs in Latin America and to prepare a water law digest.

The "home base" of this program is Ecuador. (See Memorandum of Understanding, Appendix E of the Second Annual Progress Report.)

Dr. David R. Daines arrived in January of 1971 to begin his activities. His activity report to the end of the reporting period is included as Appendix C.

We are happy to report that Dr. Daines is receiving excellent counterpart assistance, especially from Dr. Falconi, the chief legal advisor to the Ministry of Hydraulic Works. Not only has he spent many days collecting all available Ecuadorian data, he has greatly assisted Dr. Daines in organizing and summarizing the data being collected from the other countries. To have a legal expert of the caliber of Dr. Falconi, whose mother tongue is Spanish, spending over half his time on this program with Dr. Daines has made a tremendous difference.

PO7: To develop and promote the use of land and water conservation management techniques for beneficial and efficient use of on-farm water for optimum crop production.

The Hydrologic Modeling of theAtlantico-3 project of Colombia using a hybrid computer has generated another progress report: "A Hybrid Computer Model of the Hydrologic System Within the Atlantico-3 Area of

Colombia, South America," by J. Paul Riley and Eugene K. Israelsen.

The report indicates that modeling of the data is entirely feasible but that it could profitably be refined with more data. The next step is to involve the regional managers of INCORA who have the capability of utilizing the model and training Colombian programmers.

PO8: Economic Component. During the reporting year, most economics phase effort was devoted to getting researchers into field situations in order that maximum data collection could be accomplished, given budget and operating constraints.

Between January and April, a 211(d) student M.S. thesis was completed (supervised by Dr. Wennergren), review testimonials were secured for a large bibliography of Latin American research reports (as organized by Daines, LeBaron, and Whitaker), 2000 questionnaires were sent to Latin American research institutions (under the direction of Percy Aitken), and the tape containing all the Michigan State Bolivian survey data was converted to a language compatible with the USU computer (retrieval supervised by Dr. Whitaker). Dr. Whitaker also made the outline for a benchmark survey of Bolivian agriculture. Dr. LeBaron (with the help of others mentioned) prepared projections of supply and demand for Bolivian agricultural products.

After the April budget data became available, the summer-fall field season was planned on the basis of an initial budget of $60,000.00.

Arrangements were made for students Lloyd and Aitken to collect field data in Ecuador, while Glenn was to do the same in El Salvador. Dr. Whitaker was placed in charge of preparing work plans, and subsequently travelled to Latin America to participate in part of the infield research. The three students left for Latin America as scheduled and all of the field research was successfully completed by early November. These four people put in more than 180 man-days in field research during the summer and fall.

The data returned to Logan has all been interpreted by the students involved. Professional staff are now reducing results to usable reports, or are waiting until thesis examinations are out of the way. Dr. Whitaker has completed a draft of the El Salvador report with the assistance of Glenn. An M. S. thesis on part of the Guayas Basin work has been submitted for acceptance. A draft manuscript combining all of the collected Ecuadorian rice data has been started.

Dr. Wennergren collected materials for part of the Bolivian benchmark study and by October two chapters had been completed by himself and Dr. Whitaker. During the summer, Dr. LeBaron supervised revision of the first Guayas Basin rice manuscript.

During part of the summer and fall, in connection with professional activities on other contract in Latin America, Wennergren, LeBaron, and Aitken continued attempts to secure price quantity information on Bolivian agricultural products, and collected a considerable quantity of additional bibliographic materials from Bolivia, Ecuador, and El Salvador. Aitken also field-tested a survey questionnaire on household consumption and village production activities in Bolivia and Ecuador.

Since a large number of economic and technical reports from several Latin countries have been collected, various plans have been considered to make the holdings available to other researchers and Latin study centers. The day-to-day direction of this work has been supervised by Aitken and LeBaron.

All of these activities are detailed in Appendix D of this report. Note that activities marked by asterisks (*) have been financed by contract other than csd-2167; the activities marked with a cross (+) have involved per diem and some pay differentials only. Details of bibliographic work are also reported, along with proposed publications and manuscripts in process. During the year under review, one preliminary research report was prepared and subsequently revised: "A Preliminary Estimate of the Long-run Demand for Agricultural Products in Bolivia," Dr. Allen LeBaron, Dr. Boyd Wennergren, Dr. Morris Whitaker, Percy Aitken, Philip Lloyd. CUSUSWASH/Ut/Econ. P 5, AID/csd-2167.

In general, the economics phase goals, as recorded in the original project work plan, and as amplified in the appendices of that plan, are deemed to still be suitable and achievable. However, we do propose to move into specific studies of the role played by water management institutions in selected areas or cases, in order to illustrate the economic constraints which may be inherent in existing policies. This additional dimension will be coordinated through the activities of Dr. Daines, and will be in harmony with his work on a source book of Latin American water laws.

During the January-April 1972 interval, at least one more field trip has been coordinated with USAID/Ecuador and officially cleared with the Latin Bureau. TAB approval is pending on this and further obligations.

PO9: To develop training and demonstration programs in water management aimed at increasing the capacity of local technicians and institutions to conserve and manage their water resources for optimum production.

General Observation

Although this is a research contract, a training and demonstration component is essential in order for the research to be performed and applied to the water management problems in lesser developed countries. The USU field researchers cannot operate outside national research programs. Operating within them means that host agency counterparts provide a large portion of the required physical and human resources required by the research. These human resources must be able to function effectively. Where their previous education and experience has been inadequate for the needs of the research activity, they must receive sufficient training to carry through their assignments. This usually means that the USU research staff must provide specialized training to their counterparts.

Demonstration usually implies a more diffused type of training where the results of research are demonstrated to potential beneficiaries. Having seen the research applied to a situation he can relate to, the individual can then modify his activities to take advantage of the new knowledge.

The following tabulation indicates the major areas of training and demonstration during the report year. It is not complete since the continuous contact of the USU researcher with his counterparts, with students, extension agents and local farmers involves him in many discussions which leave a significant impact but cannot be tabulated because of their informal nature.

COUNTRY	TRAINING	DEMONSTRATION
Brazil	Counterparts during planning sessions in Rio and with field staff on the three research stations	
Chile	Counterparts of SAG and students from the Catholic University - Water measurement - Soil moisture determination - Plot design - Yield analysis - Seed bed preparation - Plot care and harvesting	To communal farmers on irrigation and fertilization techniques, also seed bed preparation.
Colombia	Counterparts - Soil moisture determination - Installation and use of piezometers - Design of sub-surface drainage systems - Construction of mole plows - Installation of mole drains	

COUNTRY	TRAINING	DEMONSTRATION
Ecuador	Counterparts - Evaluation and summarization of legal data Rice Commission Extension Agents - Writing questionnaires - Securing economic data from farmers - Evaluating field data	
El Salvador	Students and extension agents - Principles of irrigation research including: - Using evaporation pans - Using lysimeters - Water measurement - Analyzing hydrometeorological data for water requirements studies	

APPENDIX A

TRIP REPORT - BRAZIL

by

Rex F. Nielson

August 8 to August 27, 1971

WATER MANAGEMENT RESEARCH PROJECT AID/csd-2167

TRIP REPORT - BRAZIL

Rex F. Nielson

The trip to Brazil during the period August 8 to 27, 1971 was primarily to assist Norris Gilbert and Lloyd Austin with their program. The first week was spent in Rio becoming acquainted with the program and consulting with USAID and SUVALE personnel. The second week was utilized in the Sao Francisco Valley visiting each of the farms at Pirapora, Formoso and Barreiras. The third week was used to summarize observations at Rio and to visit the University of Sao Paulo at Sao Carlos.

PIRAPORA

Irrigation System

The installation of the main pumps to irrigate the project is proceeding well. The pump base and inlet tunnel are now installed and they are constructing the pump house. The motors, pumps, and transformers, including all the hardware necessary for the installation, are on site and we were advised that within thirty days the installation would be complete. It is their projection that water should be available through the main line system well ahead of the rainy season. The main line is now completely installed. It would be my opinion that they may not have water available from this system until the next dry season.

At the present time irrigation is from a mobile pump and portable line that is set on a stand near the river. It has good capacity but it taxes the unit to lift the water as far as is necessary and still maintain a head for sprinkling. The irrigation on the field at the present time is primarily sprinkler, although furrows are used on the onions, garlic and tomatoes. Two nozzle sizes were supplied with the system, a large and a standard. The sprinklers are manufactured in Brazil and the large nozzles work reasonably well except that the large drops of water have a puddling effect on the land. The small nozzles fail to operate satisfactorily, and plans are underway to get factory personnel to find out what the trouble is. It is possible that the large sprinklers may work more effectively if greater pressure can be developed. The sprinkler system is being used on a makeshift fashion, and although it is not operating well, it does provide water to the farm.

Prior to our departure from Rio we had been informed that excavation and work on the canal for field #2 had been stopped until new plans had been drawn up. We were somewhat dismayed to find when we arrived that they were constructing the canal with plans that had been developed earlier. A rather lengthy and vigorous discussion occurred in the field at which time we strongly encouraged the field staff to not proceed with the canal, but to consider a change in design, placing it into a single plane as opposed to a series of drops as designed for the Barreiras project. It was obvious from inspecting the field that a one-slope canal will work very satisfactorily. With portable drop structures, irrigation can be accomplished effectively. The pad for the canal was constructed too high, and even when installed in a single plane it will be difficult to irrigate unless the pad is lowered. A lengthy discussion with the station personnel occurred in the field, and this was followed up later that night. We used detailed illustrations to show what we were talking about and why we were suggesting that these changes be made. Our discussions were justified as suggested changes were accepted the following day. It is the opinion of our team that the changing of this irrigation design was a major accomplishment and one that will have long-lasting benefits.

The excavation that was occurring on the canal at the time we arrived illustrates a point that I think is sympotomatic of a number of problems in Brazil. The pads had been developed and the canal was being dug by hand; however, all the excavated soil was piled on the lower side where it would again have to be picked up and hauled to the upper side of the canal where it was to become part of the road. They were concerned with building the canal and it hadn't occurred to them that they were throwing the soil in the wrong direction. When we called it to their attention they could readily see the problem, and it was immediately corrected. These kind of problems I think are typical and show lack of foresight of the individual involved to see the whole scope of the project.

Soils

The soils at Pirapora that have been irrigated appear to take water reasonably well. The one hundred meter runs are satisfactory, and further studies will be necessary before changes might be suggested. The soil is extremely hard when dry and very difficult for implements to penetrate. Provisions will have to be made so that land preparations will occur when the soil retains enough moisture so that the soil can be worked. If this isn't done, it will continue to break up equipment and poor seed beds will be developed. The soil apparently does not erode badly with furrow irrigation. The wetting front, as is characteristic of sand, is more vertical than lateral; however, it is the opinion of those who have worked with it that row widths as wide as a meter may be considered with corn and some other crops. The soil is totally undeveloped in terms of profile; organic matter is extremely low, and it is the opinion of the team that the structure and hardness will be changed markedly after some organic matter from crop residue has been incorporated.

Field Plantings (USU)

The soybean planting made by Gilbert and Austin is eight to ten inches high with fair to poor stands. The poor stand has been attributed largely to poor seed germination. Other problems developed, however, when the field workers apparently did not maintain seed in the hopper at all times, so some rows are blank. Weeds are not a serious problem, and although growth is not good, the beans look reasonably normal. In some areas where the sprinklers are putting down too much water, the beans are quite yellow and are not doing well. Examination of the root system indicates that nodulation is occurring on some beans, although many plants show no nodules.

A problem developed with the bean field early in its life: apparently when the beans were about three to four inches tall a severe wind storm developed for about a four-day period. The abrasive sand caused considerable damage to the plant's stems. This was further complicated by the fact that insect damage also became in volved, and some plants were nearly girdled in the area just above the ground. Insecticides were applied at various times involving DDT and Dieldrin, and there is no evidence at the present time of any active insect problem on the field. The damage from the sand and the insects has somewhat healed, but it has had a stunting effect on the plants and has undoubtedly influenced the total growth. The beans are at the stage where some are now developing pods. The plants, even where they are doing very well, will never be tall, probably be less than 18 inches. This is not unusual as we observed later in our trip. The field will probably be plowed in the next three to four weeks and incorporated as a green manure in preparation for a planting of corn for some supplemental irrigation that may occur during the rainy season.

Field Trials (SUVALE)

The garlic, onion, and the tomato experiments are being run by SUVALE personnel. IPEACO has provided technical help, seed and materials, but the operation of the trials is solely in the hands of SUVALE personnel stationed at Pirapora. This is in contrast to information that had earlier been available.

It was of interest to observe the trial with tomatoes involving some 15 to 20 varieties trellised on canes. The plants looked exceptionally good, some virus disease present, although it is not significant. There is a variety differential on susceptibility to virus. One point of interest was the fact that two varieties showed what had been identified as calcium deficiency. This involves a blossom end rot of the fruit and a dark necrosis on the underside of leaves. Photographs were taken so that this problem can be studied in more detail by pathologists at Logan.

The most impressive part of this experiment is that tomatoes were the first crops on land that had been taken out of native vegetation. Fertilizer and lime have been added with irrigation twice a week. Exceptional yields of tomatoes are being produced and the quality of fruit appeared to be very good. There was no evidence of any deficiencies except calcium. A point of interest is that a gross error was made when fertilizer was applied to these plots. A recommended rate was arrived at with personnel from IPEACO, but the individual actually applying the fertilizer made an error and the fertilizer went on many times the level that was initially suggested. This would suggest that high levels of fertilizers are probably going to be necessary on high intensity crops such as tomatoes. The workers are very encouraged with tomatoes as a crop. They are selling them for a good price, and they feel that this crop has a high potential for the area. The unique advantage of this particular area is that off-season tomatoes can be grown for the Belo Horizonte-Brazilia market.

A vineyard was being planted with 20 to 25 varieties of grapes. This involved excavating a trench to a depth of about 40 to 50 cm. Manure and lime was then added with the soil and placed back into the trench along with the rooted grape cuttings. The vineyard is located on field #5 and is being layed out to irrigate parallel to the canal. It would have been desirable if the orientation might have been made the other way. They were concerned with excessive slope and planned it across the slope as opposed to placing it at right angles to the canal. This will not pose major problems; however, it will be necessary to run a lateral lined head ditch to prevent erosion. This planting is being made at an accelerated pace since the cuttings are being shipped from a cool season area and will be sprouting when they arrive.

The onion and garlic trials are well advanced, with the garlic almost being ripe. These trials were established before the fields were leveled, and they are being paddy irrigated.

A bean variety trial had been recently planted with excellent stands. Sprinkler irrigation was being used with only a fair distribution pattern because of the large nozzles.

Equipment

A major problem is evident as there is no cultivating equipment on the farm to cultivate row crops. The people involved have had no concept of cultivating row crops for weed control, and consequently there is not a single cultivator in the entire Sao Francisco basin. The only tool available is a digger type tiller. This is good for land preparation if the land isn't too hard; however, they have been using this tool on extremely dry hard soil and it is now broken. A furrowing rig is available of unusual design and of little practical use. It has no penetration capability and as a result is broken easily in the hard soils. If a program with row crops is to be conducted, it would be absolutely necessary that a cultivating rig be acquired to do two things: allow cultivation for weed control between the rows, and most important, a shovel arrangement whereby the furrows can be made for furrow irrigation. The Brazilians recognize the problem because they have had great difficulty in making furrows. The overall view of the equipment on the farm is good. All the equipment suggested in the original report has been acquired, is on the farm and in good operating condition. The farm shop at Pirapora is good, and the mechanics there are capable of making most repairs.

One deficiency exists in equipment in addition to the cultivator problem, and this is a placement tool for side-dressing row crops. The corn planter which can also be used for planting beans, soybeans and large seeded crops has a large fertilizer attachment, but this is not designed for a precise placement. The team will make an effort to investigate what equipment might be available in Brazil to move ahead and acquire what is necessary.

Support Facilities

The physical plant to support the experimental farm is nearly complete. The headquarters unit has been finished with the renovation of the old farm home for an office building. The office is air conditioned with adequate space for staff and secretary. The storage shop for parts and equipment adjacent to the headquarters unit is in operation. Provisions to date have not been made for seed storage. This will be necessary as a seed program develops. The problem of maintaining humidity at a low level, insect control and rodent control will be paramount as the station grows into a fully operation unit. The need for this facility is very apparent, and plans are being made for Gilbert to supply the technical help from his earlier work. He will also contact Mississippi State who has a USAID contract relating to this problem.

Staff

The technical staff located at Pirapora appears to be quite satisfactory. The station superintendent is Toledo, a young Brazilian who has a keen mind, an active interest in the program and is seriously involved in trying to get a good job done. Suzaki, the agronomist who is working with tomatoes, is very much interested in his work and appeared to be very capable.

The unit area director for SUVALE is a very personable individual. He was with us in our field activities and also at the night meetings.

Suggestions

It would appear to me that some work needs to be done as early as convenient relative to the water holding characteristics of the soil. Some work has been done by the Bureau team on infiltration rates. It is hoped that additional work might be done sometime before the rainy season, if not well ahead of next year's dry season. It is necessary that these soils be characterized so that irrigation regimes can be based on a sound data.

We discussed in detail proposals for supplemental irrigation during the rainy season with the idea that this may prove very valuable to crops when periods of drought occur. This plan was received with enthusiasm, and it is likely that a program will be developed for some irrigation in the rainy season. It was discussed that comprehensive plans are being developed by the Utah team to cover various aspects of field experiments involving fertility, irrigation, varieties and spacing. Plans are completed for some experiments and are in the process of being developed for others. They will be made available to SUVALE personnel for their consideration and use.

The discussions at Pirapora suggest that the staff is committed to moving ahead with a substantial program, although there had been considerable delays, and I am sure that additional delays will develop in the future. The total concept of teamwork has not been fully arrived at at this station. Some members of the station are not working together for a common cause. We are of the opinion that SUVALE personnel are receptive to most of the suggestions we had made. They repeatedly voiced the opinion that they were working as pioneers in an area where they had no experience and they most welcomed suggestions from anyone who had experience in this area. It is quite apparent that the Brazilian technicians not acquainted with irrigation have a considerable fear of the complexities of handling irrigation water.

The overall evaluation of the Pirapora site would be that the potential exists at this location for an excellent experimental farm. The topography is good, the general layout and physical plant that is being developed are most adequate for current research, and land is available for additional expansion. The technical staff is there and the support of SUVALE in terms of funds appears to be quite adequate. We have no evidence that there is a shortage of money stifling any of the programs. It will merely be a matter of the USU team motivating the technicians to move along into areas of research where they have had no experience and have no technical competence. This is planned and will be carried out as the program develops. It will be necessary that both Gilbert and Austin make repeated visits in order to keep in close contact with work going on at critical periods of time. This will not necessitate that they be in residence constantly but only at key times when needed to provide the technical aid to make sure that the trials move along in a manner that is satisfactory for all involved. The personnel on the station express a keen interest in having this help and would like to have the team on site constantly which of course is not possible.

FORMOSO

Field Planting (SU /ALE)

The situation at Formoso is quite different than that at Pirapora. A series of detailed variety trials are being conducted on lowlands where they have a sprinkler irrigation capability. This unit is being operated with a portable sprinkler system pumping from the Formoso River. It is relatively short lift so that pressures at the sprinklers are considerably greater than at Pirapora. The crops being grown are corn, sorghum, beans, peas, alfalfa, wheat, okra and mellons. The corn has very good stands and excellent color, indicating adequate nitrogen. I was surprised to hear that fertilizer had not been applied to this site. The technicians advised us that sufficient nitrogen was available in these soils taken out of timber to supply the needs of crops for some three years.

A serious problem exists, however, as the corn has been planted with a drill set at a high rate and consequently is very thick. Some corn is in tassle and it is unlikely that they will get a good set of ears with the very close spacing within the row. The between the row spacing is about one meter which is adequate. The grain sorghum looks very good and yields should be quite exceptional. Some of the sweet sorghums are also producing excellent forage. Bean yields were good, but peas look relatively poor. The wheat crop was not good and it would be my estimate that yields will probably be less than 25 bushels per acre. The technicians were somewhat perplexed by a variety that had failed to develop heads. This is obviously a winter-type that was not vernalized and did not flower. It would be my impression that wheat is not adapted to this site. Okra was growing very well and it is obviously a crop that can be produced satisfactorily.

Soybeans were being grown but the plants were small, stands were thin and yields were poor. The beans reflect some of the problems that were observed at Pirapora. The varieties were not adapted or they planted at the wrong time of the year. The fields at Formoso were relatively clean; however, weeds had been a major problem as evidence of considerable hoeing was present.

There is a non-irrigated grass planting out near the landing strip involving varieties and clipping.

Irrigation System

The major pumping station at Formoso is now operational. The first time this unit was tested, however, the main line burst and this has not been repaired. The pumps are turned on occasionally to keep them from freezing. The canal that the main line is pumped into has been deteriorating and is not usable at the present time. Even if the main line is repaired, the remainder of the canal will continue to pose a problem. The land has been only superficially leveled on the experimental area.

The Formoso site, as has been indicated in earlier reports, is not well suited for surface irrigation. They have selected the best areas and will have these prepared eventually for the irrigation experiment farm, but this is some time in the future. The design problem with the canals is being reworked at Rio with Austin's suggestions being incorporated. The development of irrigation is going to be difficult under all conditions, as the slope of the best land is in excess of 2-1/2 percent. There is little possibility for developing bench terraces because serious problems would develop with the exposed subsoil. We were advised that some of the areas would be planted with cotton and will be irrigated, but I would anticipate major problems with furrow irrigation, particularly with inexperienced personnel.

It is the opinion of the team that it is unlikely that the test area will be developed to a point where any experimental work can be carried out with irrigation variables during the next first two years. This site is apparently a low priority and is not receiving the attention that has been placed on the other two farms.

Support Facilities

The development of physical plant in terms of living quarters, warehouses, equipment, is moving along at a slower rate than at Pirapora. There is a general tendency among SUVALE's organization to be concerned with colonization and production as opposed to research. This situation prevails at Formoso.

BARREIRAS

Irrigation System

The permanent pumping station has been installed with a pipeline extending from the river to the top of the farm. There it connects with two concrete ditches that run down the center of the farm with a roadway in between. The irrigation canals that have been installed are massive in nature, probably twenty times as expensive as necessary. The design for this system was apparently from a Bureau of Reclamation Handbook with a scale down of the whole system resulting in a water conveyance canal as opposed to a canal designed for siphon irrigation. The system involves a series of drop structure with a maximum drop from the top of the ditch to the land in excess of one meter. The velocity of the water coming from siphons will be sufficient to cause considerable erosion and difficulty in handling water. The design of the canal is such that it is not possible to develop bench terraces, as the terraces would be too narrow and quite unworkable. If this canal had been installed in a one grade system with permanent checks in the canal and with temporary checks being used for irrigation, the system would have been far more effective. The design of the canal is such that it would carry up to six second feet of water, but the flow of the water from the pump does not exceed one second foot at the head of the field. The agronomists have tried to pre-irrigate on some fields in preparation for planting and are well aware of the problems that are going to be involved in handling water.

At the present time the one canal is almost entirely complete, and the other is more than 2/3 done. It is likely that the entire system will be installed before the rainy season. The problem that confronts the USU team is to how to make the best of a bad situation and prevent it from occurring in other areas. As has been indicated earlier, we recognize the problem on this site and have made provisions so that it is not repeated at the Pirapora station. It is my opinion that the USU contract failed to recognize the lack of experience of engineers in Brazil to design an on-farm irrigation system that would be effective. The need for engineering help is now obvious. Perhaps this should have been anticipated, but needless to say, this wasn't done. The burden of guilt for this engineering monstrosity will have to be borne by all the parties involved with this project.

Suggestions were made on modification of siphon equipment so that velocities of water could be reduced to a point where they would not be erosive. The problem of eroding the berms of the sides of the cement ditch has not been solved, and this is a constant worry to the agronomists with approaching rainy season. The agronomists will be plagued with an irrigation system that is difficult to handle, but I think with modifications some success can be achieved. It is anticipated that a sprinkler system will be purchased and the most difficult areas sprinkler irrigated to alleviate the problem.

Support Facilities

The physical facilities in terms of buildings are just beginning to be constructed. The footings for the first buildings are now in place, and construction will take place as soon as the concrete ditch has been completed. A rather elaborate headquarters unit has been developed in the city of Barreiras and shows the keen interest in SUVALE in developing this area.

Equipment

The problem with the lack of cultivation equipment is the same as Pi.apora. It will be necessary to obtain these tools for the installation of furrows and also for cultivating row crops. The soil is very hard during the dry season and existing equipment is not of sufficient strength to be effective. The devices that are currently being used are being torn apart and are not at all satisfactory. It is hoped that new equipment can be purchased from Sao Paulo and delivered to the site in sufficient time for furrowing prior to the rainy season.

Research Program

A night meeting was held at the SUVALE office to present a number of the research programs that had been discussed previously at Pirapora. The program for the rainy season and for the subsequent dry season was planned and the input of the USU team is anticipated to be considerable.

The current plans of the agronomist at the station are to make a planting as soon as the final installations are made on the irrigation system, which is perhaps only a matter of a few weeks away. This planting will involve seed increase of both beans and corn and will be made in advance of the rainy season. The staff at the station appeared to be very competent and is composed of young agronomists who are eager to do the right thing and accomplish good practical results. It is my opinion that this station will develop and show some very positive results in the not-too-distant future.

Key SUVALE Personnel

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Domício do Nascimento Junior
Chefe, Secão de Pesquisas Agropequarias

Emmanuel Landau, Chefe, Divisão Irrigacão

Avelino Costalonga

Fernand_ Rodrigues Fernandez

*The underline denotes the name by which they are known.

Lairson Couto

José Lucindio de Oliveira

2. Pirapora: José Lontras Fagundes
2a. Agência Regional da SUVALE
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Antônio Toldeo

Francisco Mozart Cisne Frota

Shinobu Suzaki

Rolando Oliveira Coronado (The Peruvian)

Marcelo Mameluque Mota

3. Barreiras: Vivaldo Cecílio de Motta
3a. Subagência Regional da SUVALE
Barreiras, Bahia, Brazil

Francisco Lessa de Souza

Tarciso José Caixeta

Walter Caldas, Jr.

Davi Soares Pinto

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4. Juazeiro: Joao Nelly de Menezes Regis
5a. Agência Regional da SUVALE
Juazeiro, Bahia, Brazil

<u>Observations</u>

I was most interested to see the progress that had been made by SUVALE to implement the program suggested by Peterson, Nielson and Anderson in their report of September 1969. All the suggestions made in this report have been followed with few variations.

It was also pleasant to renew acquaintence with the Brazilians and USAID personnel I had met on my two earlier trips. I am convinced the matter of personal diplomacy goes a long way in developing programs.

The USU team is now well established with housing, transporation, social contacts, etc., so their personal lives have assumed the normal role.

Some problems occurred early in the program as a result of misunderstanding and lack of communication. These problems have now been resolved. The working relationship between the team and SUVALE is very good. Both the Rio and field staff recognize the help that the team can provide in conducting irrigation research. This situation was improved in part by discussions that developed while I was in Rio. There had been some concern on the part of key personnel in SUVALE that the USU team was using SUVALE to do research for the benefit of USU. This concept has now been changed.

The team appeared to be somewhat hesitant to become actively involved with anything but field research. This condition resulted from a misunderstanding at the time they were briefed before leaving Logan.

The present philosophy is that their program is broad enough to include any activities that are necessary before research can be initiated.

It is fortunate the team has the help and support from AID/Brazil through Bill Shimasaki. This man is an effective expediter, capable of cutting through red tape to see that programs go. His position is such that he can communicate with top SUVALE administrators when team problems cannot be resolved in any other way. I feel the conditions are favorable for the team to have a major impact on SUVALE's research program. The enthusiasm is present at all levels to get the job done. The cooperation now underway with USU, SUVALE, IPEACO and other Brazilian agencies is a sign of a progressive attitude. This did not exist when I was in Brazil two years ago.

SAO CARLOS

The following information relates to a trip to Sao Carlos with Mr. Shimasaki of USAID/Brazil. This is a city inland approximately three hours by car from the airport at Sao Paulo to Sao Carlos. The purpose for travelling to this city was to check the feasibility of a small irrigation project that is being promoted by the head of the Department of Hydraulics at the University. The state university, with 1,000 students, is relatively new and is growing rapidly. A small shallow reservoir seven kilometers long and one kilometer wide that has been used to supply water to a hydroelectric plant has been given to the University for research and

and teaching. The minimum stream flow from this reservoir is two cubic meters per second. During the rainy season this flow increases appreciably, and the storage capacity of the reservoir is adequate. It would be possible to irrigate a sizable acreage of land with this water supply. Dr. Vieria, the Department Head, is a hydraulic engineer and apparently has little concept of irrigation or the problems involved with it. The University is an engineering school with no capability in agriculture.

A large amount of contract work has been done to map the soils below the reservoir with the idea that these lands would be irrigated from gravity canals. Much of the land that is proposed to be used is very steep and would be extremely difficult to irrigate with furrows. A major concern is that the amount of land that could be brought under the project is somewhat limited and costs would be prohibitive. A further complication is the fact that most of the land under the gravity canals is privately owned and I am not sure the landowners would either want or be able to afford to pay for an irrigation system.

There is some interest in doing irrigation research on the Cerrados lands. These are lands that support the scrub trees and brush similar to areas we are working with in the northeast. The soils are very sandy, a grey to redish-grey in color. There are large blocks of Cerrado soils owned by the State on both sides of the reservoir; however, these soils have not been mapped. The topography of these areas appears to be suitable for irrigation.

We were advised that even though the University has no agricultural capability, there has been considerable liaison between the University at Sao Carlos with the people in agriculture at Campinas and Perasacabo. In addition, the state farm located on the upper part of the reservoir is also interested in cooperation. The state farm has equipment and tractors which would make it possible to conduct some agricultural research. This farm has a large reforestation project underway with most phenomenal success growing southern pines from the United States. They are growing on the Cerrado soils, are only three years old, and are at least twelve feet high. It is interesting to note that the pines look very good; however, within a few feet the native scrub is very poor.

After a long discussion with the personnel at Sao Calos I think we convinced them that their original plans of building an elaborate canal system with inverted siphons to irrigate the area below the dam is not a feasible project, at least for the first phase. We suggested that if they intend to proceed with an irrigation program they should evaluate the soils that have not yet been mapped on the Cerrados section on both sides of the reservoir. There are several small streams that run from these areas into the reservoir, and the change of elevation may be sufficient to allow gravity flow of water from the streams to irrigate an area that might be selected for the experimental farm. In the event that this is not feasible, it would be possible to pump water from the reservoir to an elevation where it could be used for gravity irrigation.

Winds are most severe and sprinkle irrigation would be almost impossible. Dr. Vieira told us that he has measured winds in excess of 100 km per hour. During the time we were there I would estimate wind velocity of 15 to 20 mph both day and night. Dr. Vieira is a most energetic man and is full of ideas. He is concerned with getting a cooperative effort developed between Campinos, Persacabo, the state farm and the University of Sao Carlos.

It would appear that it is possible that an experimental farm of 15 to 20 hectares might be developed on the Cerrado soils adjacent to the reservoir, either with natural flow or with pumped water. It could provide some information to be used for the development of the Cerrados as they occupy a large area.

When we questioned what input USAID or USU may have in the program, we were advised the University would like help during the initial layout and development of the farm, and after that time they could carry the program themselves. Dr. Vieira suggested that a period of six months would be adequate to develop this program. Shimisaki is of the opinion that a year is more likely a feasible period.

Our visit at the University ended on a very amiable basis. We suggested that they conduct the soil survey that will be necessary to decide whether or not the land in question is suitable and to investigate

the feasibility of diverting some of the streams that flow across the area to see whether or not gravity irrigation is possible. Dr. Vieira seemed somewhat relieved to find out that the rather complex project is not feasible. Further contacts may be made at a later date when new information is available. See: Dr. Rui Carlos de Camargo Vieira
Universidade de Sao Paulo
Escola de Engenyaria de Sao Carlos
Departamente de Hidraulica e Saneamento
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APPENDIX B

ANNUAL PROGRAM PROGRESS REPORT

BRAZIL

by

Norris W. Gilbert

and

Lloyd H. Austin

ANNUAL PROGRAM PROGRESS REPORT
WATER MANAGEMENT RESEARCH TEAM
UTAH STATE UNIVERSITY - USAID/BRAZIL

1. Summary of Original Program Objectives

The original objectives of the USU/Brazil program are contained in Paragraph "B" of the Memorandum of Understanding and Agreement as signed in December 1970 by officials of Utah State University, USAID and SUVALE. That document indicates that the primary objectives are to provide advice and assistance to SUVALE in planning and executing a program in Water Management Research. This program will develop data and information to be used in evaluating studies, in supporting farmer education programs for efficient use of on-farm water for optimum production of agricultural crops, and in guiding the development of irrigation projects. It will also assist in the training of SUVALE staff to plan and carry out research and the demonstration of research results in Water Management.

2. Description of Work Accomplished to Date

The work of the USU Water Management Research Team is prescribed in general in the above cited document. The team is based at SUVALE headquarters in Rio de Janeiro where cortinuous contact is maintained with counterparts in SUVALE, with the U.S. Bureau of Reclamation Team which also is advisory to SUVALE, and with ENRO in

USAID. Field work is primarily centered at three locations: Pirapora, in Minas Gerais, and Formoso and Barreiras in Bahia where SUVALE is developing Irrigation Training Centers, referred to hereafter as CTIs. These installations will serve as experiment stations, and also later on as demonstration farms and as centers for the training of farmers in the practical aspects of irrigation farming.

Upon arrival in Brazil the USU team found that none of the CTIs were ready to begin experimental work under irrigation. Although the land had been cleared, fields laid out, and water distribution systems designed, land levelling had not been completed at any location and the means of delivering water to the field did not yet exist. Furthermore, the technical staffs of two of the three CTIs included no one with any practical irrigation experience. At the third location, Formoso, a small sprinkler irrigation system was in use for forage production. In the six months since the team's arrival in Brazil the following progress has been accomplished.

In general the USU team has established excellent working relationships with all entities and counterparts related to its work. It has gained the confidence of its principal counterparts at SUVALE headquarters and at field locations so that its recommendations are followed to the greatest extent possible within the limitations of SUVALE. The team is now able to plan its work and field activities and generally obtain approval for them. The team gratefully acknowledges the support from the USU campus and USAID in these accomplishments. This support consists mainly of the TDY visits of Rex F. Nielson in August 1971, and of the efforts of Mr. William M. Shimasaki, USAID Contract Representative, who is a practical irrigation engineer, to stimulate effective field activity.

PIRAPORA

All fields originally planned for furrow irrigation had been levelled. The pumping plant is completed and operational. The water distribution system is not complete but provisional facilities are able to deliver water to any part of the CTI. Using these provisional facilities both furrow and sprinkler irrigation were initiated by the USU team for the training of CTI personnel and for the activation of experimental and soil conditioning plantings. Three simple variety tests with horticultural crops and one with beans were grown to maturity under irrigation during the dry season. One 7-1/2 acre field of soybeans for green manure was grown under irrigation and turned under. With the beginning of the rainy season in late October a number of experimental plantings were being initiated, several of which involve differential rates of supplemental irrigation in case subnormal precipitation should occur.

Furrow length and infiltration tests have been made. A standard meteorological station has been completed and personnel are being trained to operate it. An effective cooperative agreement, backed up by a substantial exchange of funds, is in operation between SUVALE and IPEACO, a regional research agency of the Ministry of Agriculture. The agreement provides that IPEACO will supply the Pirapora CTI with technical information, propagating material, fertilizers and other agricultural chemicals, and the services of IPEACO specialists in the various disciplines as the need arises. A representative of IPEACO, an agronomist, is in residence at Pirapora to facilitate the provisions of the agreement.

FORMOSO

Almost no progress has been made at this most remote location in readying the CTI for experimental work under irrigation. Although the pumping plant is operational, the canal leading to the CTI is in such bad repair that it cannot be used. None of the Lateral Ditches have been constructed and land levelling is only partially completed. The team has persuaded the Irrigation Division of DVR to alter the design of lateral ditches to reduce cost of construction and facilitate siphon removal of water from them. The original plans resembled the design of the canals at Barreiras which are such a problem to use. There is little hope that conditions for starting irrigation experiments will occur by the beginning of the next dry season. A small portion of the CTI is being planted with experiments to develop cultural information under rainfall conditions. Supplemental irrigation (sprinkler) may be applied if the need arises, using portable equipment. A series of adaptability trials to test varieties of many crops was grown under sprinkler irrigation during the dry season just ended on unlevelled land outside CTI boundaries.

BARREIRAS

The pumping plant and pipeline were already in upon arrival of the USU team. Construction of the canal system had been started and was finished by the end of this report period. All levelling was completed except for some bench terracing in one field. However, this work was not completed in time to permit any irrigation experimental work to be done during the dry season just ending. Furrow and infiltration trials were run. About half of the CTI area was planted with green manure and variety adaptation trials and irrigated up before the actual onset of the rainy season. The balance of the CTI is being planted with soil-building and other crops for growth under rainfall conditions. At least one experiment is being planted that involves differential moisture levels by means of supplemental irrigation during the rainy season, should the need arise.

A cooperative agreement exists between SUVALE and IPEAL, another regional agency of the Ministry of Interior for the support of experimental work at Formoso and Barreiras. However, this agreement has been in existence in a dormant state for a long time and its full potential has not yet been tested or well understood. Presumably it eventually will perform essentially the same function for those two CTIs as the IPEACO agreement serves for the Pirapora station.

3. Review of Roles of USU Team and the Host Country Agency Staff in Accomplishing the Program Objectives

The role of the USU team, as visualized before actually arriving in Brazil, was that of a water management research team, devoted primarily to the pursuit of information necessary to the development of irrigated agriculture in the Sao Francisco Basin. It was understood that conditions already existed for beginning such a research program. The immediate objective was to initiate experiments at once that would yield significant information concerning plant-soil-water relationships. It was hoped and even expected that by the end of the dry season (just ended) some data would already have been obtained. The role of providing technical assistance was to be avoided except as it related directly to the development of the team's research work.

As already indicated in "2" above, the team did not find conditions permitting an immediate start of research activities. In fact, it is very doubtful that very much data of significance other than those of furrow and infiltration tests can be obtained before the end of the team's first twelve months in Brazil.

The role of the USU team, then, has been one of studying and trouble-shooting SUVALE's CTI development plans and advising on corrections and alterations. The team actually works with two groups of personnel. The first and most important consists of CTI technicians and local administration who have to do most of the actual development work, both planning and execution. But the CTIs are not autonomous and must proceed according to plans approved by SUVALE headquarters. Thus, it has been necessary to work closely with high level administrative personnel, the second group, which is in general more deficient in practical experience than the field technicians.

4. & 5. Obstacles Inhibiting the Progress of the Work and Action Taken or Contemplated to Overcome the Obstacles

Probably the chief obstacle to progress is the basic philosophy of SUVALE which emphasizes the development of material things rather than people, which permits the development of inadequate plans based on incomplete and often erroneous information, and which favors the contracting of services rather than the internal development of service capability. Most of the definable obstacles can be traced to these weaknesses in SUVALE policy; for example, SUVALE has ample funds for contracting construction of buildings, canals, surveys, and feasibility studies, and for purchasing equipment. But its salary scale and employment policy discourage the recruiting of more capable technicians. Absolutely no attention has been paid to building libraries of technical information, either at headquarters or at field locations. Equipment is purchased without much regard to its utility. Such obstacles are difficult to deal with because they stem directly from policy. Personnel competence cannot be markedly upgraded until compensation is made more attractive. The widening of the technical knowledge of staff will not occur until increased training opportunities are promoted by SUVALE Administration. Effective technical libraries at CTIs will not materialize until Administration is convinced of the necessity for them. The acquisition of the proper machinery and equipment for conducting field research will not occur until purchasing policy places more emphasis on the correct specifications and less on price. Some dialogue between SUVALE personnel and the USU team has laready occurred in these areas and more will occur, particularly where there is some hope of achieving results.

Some other more specific obstacles can be mentioned about which positive action already has been or will be taken. For example, SUVALE does not have at any of its installations any facilities for proper seed storage. This results ingreat difficulty in acquiring seed well in advance of planting dates and holding it under safe conditions until used.

Steps have already been taken to acquire a commercial size dehumidifier through the USAID/Mississippi State University Contract. This equipment will be installed in a suitable building at Pirapora which will serve as a central seed storage facility for all the CTI stations. Moisture-tight drum storage using silicated or some other dessicant will be provided for short-term storage of small lots of experimental seed at individual CTIs.

It appears that the DVR (Diretoria de Valorizacao Rural) of SUVALE tends to regard the USU team members as employees of SUVALE and does not always assign headquarters counterparts to accompany them to the field. Thus, opportunities for training headquarters based technicians are lost. The team is stiffening its resistance to this situation but it is not always avoidable.

Travel problems present a real obstacle to progress. Travel requests on several occasions in the past have been arbitrarily denied by the Director to the detriment of field work. Commercial plane schedules make it very difficult to make efficient use of time in visiting Barreiras especially. SUVALE's private planes have often not been available to the team. The weather also has thwarted travel plans on several occasions. Most of these problems cannot be avoided. But beginning in September the team began trying to program its travel enough in advance to reduce the hazards of request denial and plane scheduling problems.

At Barreiras the CTI is situated some 12 to 15 kilometers from town where SUVALE's Sub-Agency headquarters are located. The Sub-Agency has inadequate transportation facilities which hampers the activity of technical personnel assigned to the CTI. Besides, local leadership at Barreiras is weak and the agronomist who had assumed what leadership was exercised in the development of the CTI has transferred to another post. Office, repair shop and equipment storage facilities are under construction at the CTI but personnel are going to be reluctant to use them effectively in view of the distance from Barreiras and the poor condition of the road during bad weather. The team has urged the basing of CTI personnel at the CTI rather than at the third Sub-agency headquarters in Barreiras and the designation of one of the agronomists to assume leadership of the development and operation of the CTI. Through its contacts with the USBR group which has been on the SUVALE scene for years, the team has learned something about the internal policies of the DVR in particular.

6. <u>Current Assessment of the Validity of the Original Objectives</u>

In the opinion of the USU team the original objectives as stated in "1" above are still valid in every respect. The only modification contemplated is for the team to assume positive leadership in those activities and developments where their SUVALE counterparts are incapable or unwilling to exercise it. The development of a seed storage facility is an example. Although seed technology is rapidly developing in Brazil, no one in SUVALE has been impressed with the necessity for including it in their long range plans. The team's knowledge and experience in that field are solely responsible for starting the development of seed storage facilities within SUVALE.

APPENDIX C

ACTIVITY REPORT OF

PO6 - WATER RIGHTS DIGEST PROGRAM

by

David R. Daines

WORK SUMMARY FROM

JANUARY 18, 1971 TO NOVEMBER 18, 1971

a. 1 month - Regional and Ecuadorian. Orientation, collection of materials, general study and development of a framework for a digest and comparative study. January 18th to February 18th, approximately.

b. 2 months - Collection and study of materials related to subject in Ecuador. Organization of materials and completion of a rough draft of the Ecuadorian part of the digest. Done between February 18th and April 18th.

c. 1 month - Regional. Collection, study and drafting of digest draft related to Peru. Peruvian draft about one-half complete at this stage. Done between April 18th and May 18th.

d. 1 week - In Colombia collecting materials and studying their system for water administration for use in the digest. This was regional work completed between May 24th and May 29th.

e. 1 week - In El Salvador reviewing and collecting information water rights and administration in Central America for the purpose of determining the compatability of the framework for the digest with the water law regimes in those countries for future possible expansion. I was in El Salvador from May 31st to June 3rd and this work was regional.

f. 2 weeks - Contributing lecturer and participant in Water Planning Conference held at Utah State University from June 7th through June 18th. This was regional work.

g. 2 weeks - At the request of USAID/Colombia and Colombian authorities, I consulted with Colombian authorities on areas of needed changes in water legislation and how to accomplish these changes. I also prepared for them a portfolio of written information and commentaries on the areas of proposed changes. I was in Colombia from June 23rd to July 1st and prepared a written report after my return to Ecuador.

h. 1 week - Ecuadorian work. Reviewed the provisions of a proposed water code under consideration by the President's legislative review commission and prepared comments thereon jointly with INERHI's legal department.

i. 1 week - Ecuadorian work. A combination of a field trip and consultations with INERHI and the Commission for the Development of the River Guayas Basin on regulations and administrative structure for water distribution within the basin. This was in the first part of September.

j. 1 month - Completed collection of Peruvian materials and finished the digest rough draft for Peru. This was done from the end of July through August. Regional work.

k. 2 months - Regional work. Collected and reviewed materials for the digest on Chile and completed the rough draft of the digest provisions. This was done primarily in the months of September and October.

l. 2 weeks - Regional. Continuation of the Colombian phase of the digest work completed in the first two weeks in November.

m. 1 week = Ecuadorian work. Reviewing documentation on the Puyango-Tumbes Bi-national Ecuadorian-Peruvian international project to determine the scope of work in the legal aspects of the pre-feasibility studies. Conferences with the Chief of the International Expert Team.

APPENDIX D

ECONOMICS PHASE

Prepared by

Dr. Allen LeBaron

UTAH - Economics Phase | AID csd/2167 | January 71-January 72 and Proposed

Country	Personnel	Days	Activities and Initial Output	Counterparts and Agencies	Set-up Effort
I.					
Ecuador	Aitken (S) July-August	30	118 farm budgets on production and water use practices - low income rice producers - Guayas Basin. Draft mss. on returns to small scale water investments.	NRC provided 6 of their 8 rice agents for over three weeks	Wennergren + 2 stops 5-6 days (May-August)
	Lloyd (S-D) Sept.-Oct.	54	Returns to water investment in Milagro Project by comparing collected farm records from participating and non-participating areas - small farms with mixed crops. M.S. thesis Feb. 72.	Econ. section INERHI provided all field travel and domestic air fares	Wennergren + 2 stops 4-5 days (Aug.-Sept.)
	Whitaker (P)	8	Field survey check and revised work plan for Lloyd.	" "	——
			Proposed		
	1. Glenn (S) Jan.-Mar. 72		Expected returns to planned water investments in Cooperative Guaranteed Loan Program. Field surveys as necessary to detail existing earnings on land to be developed.	Banco Central & Ministry of Production Development Team	LeBaron + 1 stop 3 days (December)
	2. ?		Potential impacts of Guayas Basin irrigation investment on agricultural labor.	NRC	
	3a. ?		Results of water investment in Guaranteed Land Sale Program.	Banco Central	
	3b. ?		Economic disincentives of water institutions, laws and management in the Guayas Basin.	INERHI	

S = Student S-D = 211-D Student (stipend, travel and per diem) P = Professional Staff

+ = Only stop-over per diem and small salary differential from csd 2167

Country	Personnel	Days	Activities and Initial Output	Counterparts and Agencies	Set-up Effort
II.					
El Salvador	Glenn (S) July-Nov.	95	Farm budgets on production and irrigation practices and investment - dairy farms in Sonsonate. Draft mss. Jan 72 on returns to water management investments.	Econ. section, irr. & drainage GOES provided local transport, 2 enumerator & 1 economist backup	LeBaron, Aitken Wennergren + 1 stop (May) 7 days Aitken 6 days July Wennergren + Sept. 1 day
	Whitaker (P) October	12	Re-check sub-sample of Glenn interviews. Revise work plan.	" "	
	* Whitaker (P) October	4	Consultant to AID/Latin Bureau on GOES Loan.	Louis Sleeper	
	Proposed				
	1. ? Apr. 72		Economic disincentives for on-farm water management due to water institutions and options under new decrees.	———	
	2. ? Apr.-June 72		Expected payoffs to water investment in Olmega Project.	Econ. section, irr. & drainage, consulting engineers	
III.					
Honduras	* Whitaker Nov 72	10	Consultant to AID/Latin Bureau on GOH Loan	Louis Sleeper	

S = Student P = Professional Staff * = Not financed by csd 2167

+ = Stop-over per diem & small salary differential only from 2167

Country	Personnel	Days	Activities and Initial Output	Counterparts and Agencies	Set-up Effort
IV.					
Chile	None		None		
	Proposed				
	? Aug.-Sept. 72		Collect adequate economic data to effectively evaluate impact of USU team's maize findings on potential of future production.		
V.					
Colombia	None		None		
	Proposed				
	? June 72		Fully implement economic phase work plan in North coast region.		
VI.					
Bolivia	* Lebaron, (P) Wennergren (P) Gomez (S)	45 45 80%	Consultants to MINAG Planning Section on creation of national plans for selected livestock and crop programs. Mss. for wheat and oilseeds; coffee, sheep, beef and oilseeds in August 72.	Planning Section MINAG (4 research assistants)	
	* Wennergren (P) & others (P)	90 90	2-3 year series of short coarses in Ag. Planning and Administration - university graduate credit is optional, about 100 participants thus far. Mss. on 1st two courses (in Spanish).	MINAG	

S = Student P = Professional Staff * = Not financed by csd 2167

Country	Personnel	Days	Activities and Initial Output	Counterparts and Agencies	Set-up Effort
	* Gomez	—	Constant pressure on statistical and planning sections of [MINAG] to collect price/quantity data at urban market centers.	MINAG	
			Proposed		
	* LeBaron, (P) Aitken (S)	90 90	Field surveys of household consumption. Estimates of apparent crop production; future demand for all products.	University of San Simon - Urban Extension Agents Community dividends Ag. Reform for Rural	LeBaron 3 days (December)
	1. ? (S-D)	30	Economics of proposed irrigation - development in Santa Cruz.		
	2. ? (S-D)		Technical and institutional factors in irrigation project collapse.	Irrigation Section, MINAZ	
	* 3. ? (S)		Economic impact of Santa Cruz road.		
	* 4. ? (P)		The role of monetary and fiscal policy in constraining growth in Bolivian agriculture.		

S = Student S-D = 211-D Student (stipend, travel and per diem) P = Professional Staff

* = Not financed by csd 2167

On Campus - Economic Phase AID/csd 2167

I. Bibliographic

A. Survey of research institutions from earlier lists of institutions collected earlier. From replies we are now able to add substantially to the Bibliography reported last year. Possibly we have 5,000+ references to papers, notes, and books on irrigation, hydrology, climatology, development problems, etc. This Bibliography will be divided into 2 parts and submitted for publication by CUSUSWASH committee.

B. An extensive listing of relevant research institutions will soon be published. The result is quite different from any of the UNESCO releases.

C. A substantial amount of material was collected in El Salvador in the past year. We now have quite a collection of holdings on the Logan campus. This listing has reached 74-80 pages and is constantly being revised as a large number of Latin American institutions continues to send their reports and publications to us.

D. Coordinate with Colorado State University on Bibliographic handbook and support CUSUSWASH publications emphasis.

I. Planned Manuscripts

A. Extension Agent Bulletin on returns to water management investments in Guayas Basin Rice cultivation.

B. Thesis report on returns to water management investments in mixed crop area, Guayas Basin.

C. Report on expected returns to newly organized coop investments in water management [rice] Guayas Basin, as related to guaranteed loan program.

D. Extension Agent Bulletin on returns to water management in improved dairy farms, Sonsonate, El Salvador. Also suggestions for dairy management practices, Sonsonate.

E. Revision of food supply and demand projections for Bolivia; also revision of income elasticity coefficients for Bolivia.

F. Preliminary employment effects of modernized rice production in Ecuador.

G. Complete book manuscript: The Status of Bolivian Agriculture. Submit to commercial publisher.

APPENDIX E

Chile

Interim Report of

Water-Soil-Crop Interaction

Experiments in Chile

1970 - 1971

ACKNOWLEDGMENTS

Dr. D. W. James, Utah State University for assistance in evaluation and analysis of these experiments.

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Carlos Rivacoba Sr. and Carlos Rivacoba Jr., owners of El Castillo, Ricardo and Hernan Rodriguez, owners of Condoroma for their full cooperation and interested participation in Part I.

Fernando Araus, Head of Soil Laboratory at La Platina Experiment Station for assistance in soil fertility analysis.

Raul Barnier, Statistics Department at La Platina for assistance in calculations.

TABLE OF CONTENTS

PART I: Investigation of the interactions between soil moisture, soil nitrogen, and plant population in the production of corn.

Objectives: (1) To test the effects of two soil moisture levels, five nitrogen fertilizer rates, and two plant populations on the yield of shelled corn at two locations.

(2) To correlate evaporation of water with irrigation water requirements of corn.

Procedure

Site descriptions: The experiments were located on two private farms in the upper Aconcagua valley near Los Andes in the province of Aconcagua. El Castillo, the larger of the two sites, was located on a deep, well drained loam to light clay loam soil with a slope of approximately one percent. The area had been in corn the previous year. Condoroma, the second site, was located on deep, well drained, very fine sandy loam to silt loam soil with a slope of about one percent. The previous crop at Condoroma had been seed lettuce. Nitrogen fertilization had been regular practice on both farms in previous years.

Experimental design: Both experiments included the variables soil moisture, nitrogen fertilizer rate, and plant population. At Condoroma, in addition, there were two different seed bed preparations. The latter were actually treated as two different experiments on the same field.

Experimental design was split-split plot in randomized complete block. The whole plot was soil moisture treatment; the first split was fertilizer rate; the second split was plant population. There were six replications at El Castillo and two replications at Condoroma. The number of replications was governed by the available space in the respective fields.

The individual plot size was 10 meters long by 5.2 meters wide at El Castillo, and 5.5 meters wide at Condoroma (six rows of corn each 34 and 36 inches wide, respectively) with 20 plots per block at El Castillo and 10 plots per block at Condoroma. Details on the field lay-out are given in Figures I.1 and I.2 for the two sites. The experimental plots were surrounded by a buffer of corn which was planted at the same time as the plots.

Site preparation and treatments:

The sites were spring plowed with a disc plow, then disc harrowed and irrigated. Seed bed preparation involved disc harrowing plus four times over the land with a spike-tooth harrow to make a soil surface mulch (to conserve soil moisture). At Condoroma a second seed bed treatment simply involved the single disc harrowing operation. This treatment was designed to approximate the method generally used in the area.

There were two levels of irrigation. The first was designed so as to avoid any moisture stress in the crop; water was applied when tensiometers placed at 45 centimeters averaged .6 atmosphere. The second irrigation treatment was applied when the corn showed wilting through most of the day. Furrow method was used and the amount of applied water was estimated by measuring inflow and outflow with 90° "V" notch weirs. The water was distributed with siphon tubes. There were five nitrogen fertilizer rates. Nitrogen in the form of urea was applied at zero, 100, 200, 300 and 400 kilos of the element per hectare. The material was applied broadcast by hand. It was disced into the soil with the disc harrow at the time of seed bed preparation. Phosphorous fertilizer in the form of treble-super phosphate was banded next to the planted two by a fertilizer attachment to the planter at planting. The rate of phosphorous was about 67 kilos of the element per hectare.

Planting at El Castillo was on September 28 but because plant emergence was not sufficient for the high population desired, the ground was given another light irrigation and replanted on November 14. Condoroma was planted October 6, 1970. The different plant populations were achieved by thinning all plots to the desired plant density. Thinning was done using wires marked with paint to give the standard distances between plants. The theoretical number of plants for the two populations was 60,000 and 90,000 per hectare, respectively. The corn variety was Chilean hybrid MA-7.

Evaporation pans:

One evaporation pan was installed at each experimental site on December 19. The pans consisted of one-half of a 55-gallon oil drum buried in the ground with approximately four inches exposed above the ground level. The pans were located in a corn field adjacent to the experimental sites and the corn in the immediate area cut to maintain a height that would prevent shading of the pan. Daily readings were taken of the water level in the pans through February 15 on El Castillo and February 25 on Condoroma.

Harvest:

Harvest data were collected from the individual plots by taking all the ears from the center four rows of corn. Border effect on the plot ends was avoided by taking only eight meters of row length using a standard wire marker for distance. The weight and number of ears of corn from each plot row were recorded. Five ears were selected at random from each row and moisture content of the grain was determined using a Delmhorst moisture meter. Yield from each plot was then adjusted to the standard 15 percent moisture content. Yield results are expressed in terms of kilograms per plot of shelled corn at El Castillo, and in terms of kilograms per row at Condoroma.

Results

Table I.1 gives the treatment and replication yield results for El Castillo on the basis of individual plots. The analysis of variance for these data, given in Table I.2, indicates that the main or direct effects of water and plant population were highly significant but that there was no significant effect from fertilizer nitrogen. The yield increased with the higher water application rate and decreased with the higher plant density. Table I.2 indicates also that there were no significant interactions. The treatment averages were converted to quintales per hectare. These data are given in Table I.3; these results indicate that the overall yield of corn was excellent at this site.

Yield results from Condoroma are given in Table I.4. In this case the yields are expressed as the mean row yield per plot (four rows were harvested). Table I.5 shows the analysis of these data and Table I.6 gives the mean treatment results in terms of quintales per hectare. The average yield results from Condoroma were lower than El Castillo but the treatment effects were essentially identical; irrigation treatments and plant population significantly affected the corn yield while nitrogen rates and interactions effects were all non-significant.

It is apparent in Table I.5 that the effect of water was not significant with the Soil Preparation 1 part of the experiment at Condoroma. This is not considered to be an important item since the error degrees of freedom (= 1) does not allow for fine distinctions among the whole-plot effects. The yield data actually did favor the higher water application treatment.

There was no significant difference in yield of corn between the two methods of seed bed preparation at Condoroma. This observation is based on a simple "t" test of the average results given in Tables 4A and 4B. There was a slight trend toward increased yield with the intensive soil preparation treatment.

Irrigation dates and depth of gross water application are given in Table I. 7. These are an average of the six replications in El Castillo and the two replications on both soil treatments at Condoroma.

Evaporation data from the buried pans for the periods between irrigations on the higher soil moisture level are shown in Table I. 8, together with the depth of water applied at the end of these same periods.

Discussion

The fact that there was no response to nitrogen fertilizer at either of the two experimental sites was unexpected. It was apparent from the lack of response, in connection with the very respectable yield levels obtained, that the residual carry-over of nitrogen in the soil from previous seasons was large enough to satisfy the needs of the corn.

In order to obtain some estimate of the amount of inorganic nitrogen in the soil, samples were obtained from the fertilizer plots at El Castillo at the conclusion of the harvest operations. The soil samples were obtained as follows: pairs of soil cores were taken from each fertilizer plot. One core came from the bottom of the irrigation furrow at a point selected at random in the plot. The second core in the pair came from a point adjacent to the first on the soil crest between furrows. The cores were separated at one-foot depth increments and were composited for each fertilizer treatment. There were, accordingly, twenty soil samples and these were analyzed for extractable NH_4-N and NO_3-N at the soils laboratory at La Platina. The results from this work are given in Table I. 9.

Looking at the soil column totals in Table I. 9, it is apparent that the fertilizer treatments had very little effect except at the highest rate. It can be assumed that the crop extraction of soil nitrogen, together with the redistribution of nitrogen within the soil by the irrigation water, had a leveling effect on the total amount of nitrogen residual from the treatments. At the same time, end-of-season levels of nitrogen were high. Table I. 9 indicates that the average total of ppm-N in each soil column was 82.4 ppm. This number can be converted into kgs of N per ha. if the bulk density of the soil is known. Bulk density was not determined here but a fair estimate would be in the range 1.3 to 1.5 for this soil. A reasonable conversion factor for converting ppm-N to kgs/ha-N would, therefore, be 3.5. Accordingly, the average amount of residual nitrogen indicated in Table I. 9 would be about 290 kgs/ha. Nothing is available in terms of the amount of organic nitrogen that would be released during the growing season so there is no way of estimating the total available nitrogen in the system. It is apparent nevertheless that there had been a build-up of soil nitrogen over the years as a result of consistent liberal use of nitrogen fertilizer by the land managers. It is estimated that the residual NO_3-N would need to be 40 ppm or lower before fertilizer to increase the yield. This assumes that soil water would be adequate but not excessive. Other kinds of nitrogen fertilizer responses will be presented subsequently in connection with the demonstrative experiments in this program.

The results indicate a decrease in yield with an increase in population density. This is opposite to the results obtained the year previous when variety Tracy-133 was used. It is apparent that under the conditions of the 1970-71 growing season, the optimum stand density was somewhere below 90,000 plants per hectare. The contrasting results for the two years emphasize the need to thoroughly evaluate corn varieties in order to be able to provide complete characterization of the soil moisture and fertility effects on corn yield.

Soil moisture availability, or irrigation frequency, affected corn yield at both locations. There were no interactions, however, between soil moisture treatments and fertilizer treatments. There are two reasons for this lack of interaction. It was evident first that nitrogen was not deficient, and second that soil moisture was not excessive. Plant growth stresses induced by out-of-balance growth factors are required if the interactions between growth factors are to be manifest. The long range objectives of this series of experiments require that the interactions in crop yield between soil moisture and soil fertility be fully defined. This is necessary in order to ascertain the optimum levels of water and fertilizer for maximum yield or economic return. Design of future experiments will be pointed more specifically toward the long range goals. The experiments presented here resulted in experience and data that are necessary prerequisites for properly designing and executing those experiments that will give rise to crop yield response functions.

At El Castillo where the yield increase at the higher soil moisture was significant, 34 percent more water was applied than on the low soil moisture. All of this additional water may not have been available to the crop, as no evaluation of the deep percolation losses was made.

For the pre-irrigation and the first irrigation after planting, the deep applications assured that the entire root zone was at field capacity. The following irrigations were lighter and at more frequent intervals to maintain the soil moisture at optimum availability.

At Condoroma, where the higher soil moisture level favored higher yields, though not statistically significant, 55 percent more water was applied than at the lower soil moisture. Total application in both treatments was less than at El Castillo. This probably explains the lower yield at Condoroma than at El Castillo. Water penetration was difficult to obtain even during the pre-irrigation.

The limited data indicate a potential for establishing a correlation between the inexpensive buried pan and irrigation water requirements. Assuming that all the water consumed by the corn between irrigations was replaced during the following irrigation and assuming an irrigation efficiency of 85 percent, the overall average ratio of consumptive use to the pan evaporation is approximately one.

The results indicate a marked yield difference between Condoroma and El Castillo. This can be explained, in part, by the differences observed in the water penetration of the soil. At Condoroma it was observed after the first irrigation that water penetration was not sufficient to affect the tensiometers even after 18 hours of continuous irrigation. This problem necessitated a change in procedure for determining the irrigation frequency at this site. Irrigation water was applied to the high moisture plots when the plants in those plots wilted at mid-day, rather than when the tensiometers registered slight moisture tension as originally planned. Water penetration was not a problem at El Castillo.

Summary and Conclusions

Field experiments on production of corn were conducted on two sites in the Aconcagua valley near Los Andes, Chile. These experiments had as variables irrigation frequency, nitrogen fertilizer rates, plant population density, and method of seed bed preparation. The major treatments were randomized and replicated in a split-split plot design. Data were collected on amount of water supplied, evaporation of water, and yield of shelled corn.

The results indicated no response to fertilizer nitrogen increased yield with the highest irrigation level, and decreased yield with the highest plant population. There were no interactions between the experimental variables. There was a nonsignificant trend toward higher yield of corn with intensive seed bed preparation. Irrigation water penetration or intake rate was a handicap at one of the experimental sites.

Table I. 1. Yield of Shelled Corn at El Castillo: Standard 15% moisture content as kilograms per plot

Soil Moisture	Population Plants per Ha.	Nitrogen kg/Ha.	Replications						Total
			1	2	3	4	5	6	
1	60,000	0	36.46	33.43	33.53	32.21	35.02	36.71	207.36
		100	34.40	34.03	31.29	32.89	35.35	34.85	202.81
		200	31.66	35.98	31.47	37.09	35.18	36.61	207.99
		300	36.42	36.90	34.23	34.12	36.77	35.08	213.52
		400	34.13	30.83	33.58	31.34	34.02	36.20	200.10
	Sub-total		173.07	171.17	164.12	167.65	176.32	179.45	1031.78
	90,000	0	34.91	34.80	30.37	33.46	35.23	34.70	203.47
		100	32.62	34.54	32.86	30.09	33.43	35.97	199.51
		200	30.28	31.77	30.07	34.72	32.12	37.08	196.04
		300	32.62	33.11	31.04	34.80	30.56	37.46	199.59
		400	33.61	31.77	29.70	33.55	32.40	32.79	193.82
	Sub-total		164.04	165.99	154.04	166.62	163.74	178.00	992.43
2	60,000	0	24.97	34.31	37.23	36.03	33.08	35.88	201.50
		100	21.60	33.82	32.53	29.29	34.18	34.29	185.71
		200	32.00	33.16	34.14	28.56	34.60	30.62	193.08
		300	31.91	21.12	28.74	25.48	34.07	26.25	167.57
		400	33.90	34.33	25.19	33.89	30.16	32.10	189.57
	Sub-total		144.38	156.74	157.83	155.25	166.09	159.14	937.43
	90,000	0	23.77	29.26	35.14	33.62	34.40	36.00	192.19
		100	20.40	35.93	27.79	26.57	26.55	32.54	169.78
		200	29.65	27.10	32.57	24.99	32.52	30.97	177.80
		300	30.96	25.22	29.48	25.39	33.72	30.91	175.68
		400	35.29	33.53	24.61	35.33	20.72	34.10	183.58
	Sub-total		140.07	151.04	149.59	145.90	147.91	164.52	899.03

Table I.2. Analysis of Variance for Yield of Corn at El Castillo

Source	df	ss	MS	F
Total	119	1703.26		
Rep	5	121.61	24.32	
Water	1	293.75	293.75	31.55 **
Error (a)	5	46.54	9.31	
N	4	64.01	16.00	.29
N x W	4	76.98	19.24	.34
Error (b)	20	914.72	55.71	
P	1	50.38	50.38	29.99 **
P x N	4	10.87	2.72	1.62
P x W	1	.00	-	
Error (c)	74	124.40	1.68	

** Significant at 1% level.

Table I.3. Average Treatment Yield Results in Shelled Corn at Standard 15% Moisture Content, El Castillo

Treatment	Average kgs/plot	Yield qq/Ha. [a/]
N-0	33.52	121.34
N-100	31.58	114.32
N-200	32.29	116.89
N-300	31.52	114.10
N-400	31.96	115.70
M-1, P-1	34.39	124.49
M-1, P-2	33.08	119.75
M-2, P-1	31.25	113.12
M-2, P-2	29.97	108.49

[a/] Nitrogen results were averaged across water and population treatments. Water and population results were averaged across nitrogen rates.

Table 1.4. Yield of Shelled Corn at Condoroma: Standard 15% Moisture Content as Kilogram per Plot Row

A. Soil Preparation 1 (Disc and Harrow)

Soil Moisture	Population Plants per Ha.	Nitrogen kg/Ha.	Replication 1	Replication 2	Total
1	60,000	0	5.49	7.83	13.32
		100	5.34	8.96	14.30
		200	6.46	8.10	14.56
		300	5.63	7.65	13.28
		400	5.53	8.30	13.83
	Sub-total		28.45	40.84	69.29
	90,000	0	4.15	7.24	11.39
		100	4.76	6.96	11.72
		200	4.30	6.87	11.17
		300	5.76	5.83	11.59
		400	4.22	6.75	10.97
	Sub-total		23.19	33.65	56.84
2	60,000	0	3.83	5.93	9.76
		100	3.70	3.71	7.41
		200	3.32	4.69	8.01
		300	6.44	6.18	12.62
		400	4.13	5.84	9.97
	Sub-total		21.42	26.35	47.77
	90,000	0	3.05	3.45	6.50
		100	2.76	3.64	6.40
		200	3.36	4.68	8.04
		300	3.40	4.04	7.44
		400	3.51	4.44	7.95
	Sub-total		16.08	20.25	36.33

Table I. 4. (Continued)

B. Soil Preparation 2 (Disc Only)

Soil Moisture	Population Plants per Ha.	Nitrogen kg/Ha.	Replication	Replication	Total
1	60,000	0	5.41	7.35	12.76
		100	7.24	7.50	14.74
		200	6.15	7.25	13.40
		300	6.27	6.49	12.76
		400	5.21	6.63	11.84
	Sub-total		30.28	35.22	65.50
	90,000	0	4.18	5.51	9.69
		100	5.75	5.43	11.18
		200	4.38	6.23	10.61
		300	5.18	5.46	10.64
		400	4.36	5.59	9.95
	Sub-total		23.85	28.22	52.07
2	60,000	0	3.25	4.49	7.74
		100	3.83	4.68	8.51
		200	3.17	3.75	6.92
		300	4.22	5.68	9.90
		400	3.28	5.49	8.77
	Sub-total		17.75	24.09	41.84
	90,000	0	2.94	3.57	6.51
		100	2.79	2.62	5.41
		200	3.52	2.52	6.04
		300	3.77	5.29	9.06
		400	3.43	3.19	6.62
	Sub-total		16.45	17.19	33.64

Table I.5. Analysis of Variance for Yield of Corn at Condoroma

A. Soil Preparation 1

Source	df	ss	MS	F
Total	39	105.64		
Rep	1	25.52	25.52	
W	1	44.16	44.16	9.86
Error (a)	1	4.72	4.72	
F	4	1.86	.47	.23
F x W	4	3.92	.98	.48
Error (b)	4	8.22	2.06	
P	1	14.26	14.26	129.63 **
P x W	1	.03	.03	.27
P x F	4	1.00	.25	2.27
Error (c)	18	1.95	.11	

B. Soil Preparation 2

Source	df	ss	MS	F
Total	39	79.74		
Rep	1	6.71	6.71	
W	1	44.29	44.29	340.69 *
Error (a)	1	.13	.13	
F	4	2.99	.75	.75
F x W	4	4.96	1.24	1.24
Error (b)	4	10.90	1.01	
P	1	11.69	11.69	64.94 **
P x W	1	.69	.69	3.83
P x F	4	.99	.25	1.39
Error (c)	18	3.23	.18	

*Significant at 5% level.

**Significant at 1% level.

Table I.6. Average Treatment Yield Results in Shelled Corn of Standard 15% Moisture, Condoroma

A. Soil Preparation 1

Treatment	Average Yield	
	kg/row	qq/Ha.
N-0	5.12	78.34
N-100	4.99	76.35
N-200	5.22	79.87
N-300	5.62	85.99
N-400	5.34	81.70
M-1, P-1	6.93	106.03
M-1, P-2	5.68	86.90
M-2, P-1	4.78	73.13
M-2, P-2	3.63	55.54

B. Soil Preparation 2

Treatment	Average Yield	
	kg/row	qq/Ha.
N-0	4.59	70.23
N-100	4.98	76.19
N-200	4.62	70.69
N-300	5.30	81.09
N-400	4.65	71.14
M-1, P-1	6.55	100.21
M-1, P-2	5.21	79.71
M-2, P-1	4.18	63.95
M-2, P-2	3.36	51.41

Table I. 7. Irrigation Frequency and Gross Irrigation Application

El Castillo			
High Soil Moisture		Low Soil Moisture	
Date	Depth cm.	Date	Depth cm.
Sept. 16, 23	21.2	Sept. 16, 23	21.2
Dec. 15	21.8	Dec. 17	19.3
Jan. 5	12.0	Jan. 27	12.0
Jan. 21	11.5	March 6	16.3
Jan. 29	5.3		
Feb. 8	4.9		
Feb. 18	7.9		
March 2	7.5		
TOTAL	92.1	TOTAL	68.8

Condoroma			
High Soil Moisture		Low Soil Moisture	
Date	Depth cm.	Date	Depth cm.
Oct. 1, 2	8.5	Oct. 1, 2	8.5
Nov. 28	5.6	Dec. 9	9.6
Dec. 9	5.7	Dec. 24	6.9
Dec. 16	6.5	Jan. 7	1.6
Dec. 22, 23	5.3	Jan. 19	7.1
Dec. 29, 30	7.6	Jan. 29	5.4
Jan. 6	3.4	Feb. 8	6.1
Jan. 15, 16	5.4	Feb. 16	3.6
Jan. 22	3.9		
Jan. 27, 28	5.6		
Feb. 4	3.3		
Feb. 10	4.7		
Feb. 15, 16	5.7		
Feb. 22	4.2		
TOTAL	75.4	TOTAL	48.8

Table I.8. Evaporation from Buried Pan in Relation to Gross Water Application

El Castillo

Period		Evaporation for Period (cm)	Gross Water Applied at End of Period (cm)
Dec. 18 - Jan. 5		12.2	12.0
Jan. 6 - Jan. 21		7.9	11.5
Jan. 22 - Jan. 29		3.8	5.3
Jan. 30 - Feb. 8		4.8	4.9
	TOTAL	28.7	33.7

Condoroma

Period		Evaporation for Period (cm)	Gross Water Applied at End of Period (cm)
Dec. 23 - 29		5.3	7.6
Dec. 30 - Jan. 6		6.0	3.4
Jan. 7 - 15		2.6	5.4
Jan. 16 - 22		4.6	3.9
Jan. 23 - 27		3.4	5.6
Jan. 28 - Feb. 4		4.9	3.3
Feb. 5 - 10		3.7	4.7
Feb. 11 - 15		3.2	5.7
Feb. 16 - 22		4.1	4.2
	TOTAL	37.8	43.8

Table I. 9. Nitrogen Soil Test Results, El Castillo

N-rate kg/Ha.	N Concentration - ppm [a/] Soil Depth - Feet				
	0-1	1-2	2-3	3-4	Total
0	40.9	19.6	6.2	11.2	77.9
100	40.3	15.7	11.2	10.1	77.3
200	26.3	15.7	8.0	7.3	57.3
300	33.6	14.6	15.1	15.7	79.0
400	57.7	25.2	16.2	21.3	120.4
TOTAL	198.8	90.8	56.7	65.6	411.9
Avg.	39.8	18.2	11.3	13.1	82.4

[a/] Extractable NH_4-N plus NO_3-N.

Nitrogen Rates
in kg per hectare:

0 - 0
1 - 100
2 - 200
3 - 300
4 - 400

Population:

60 - 60,000 plants per hectare

90 - 90,000 plants per hectare

Blocks 1, 3, 6, 8 - high soil moisture level
Blocks 2, 4, 5, 7 - low soil moisture level

Blocks 1 and 2 were dropped from the experiment due to irrigation problems during the season.

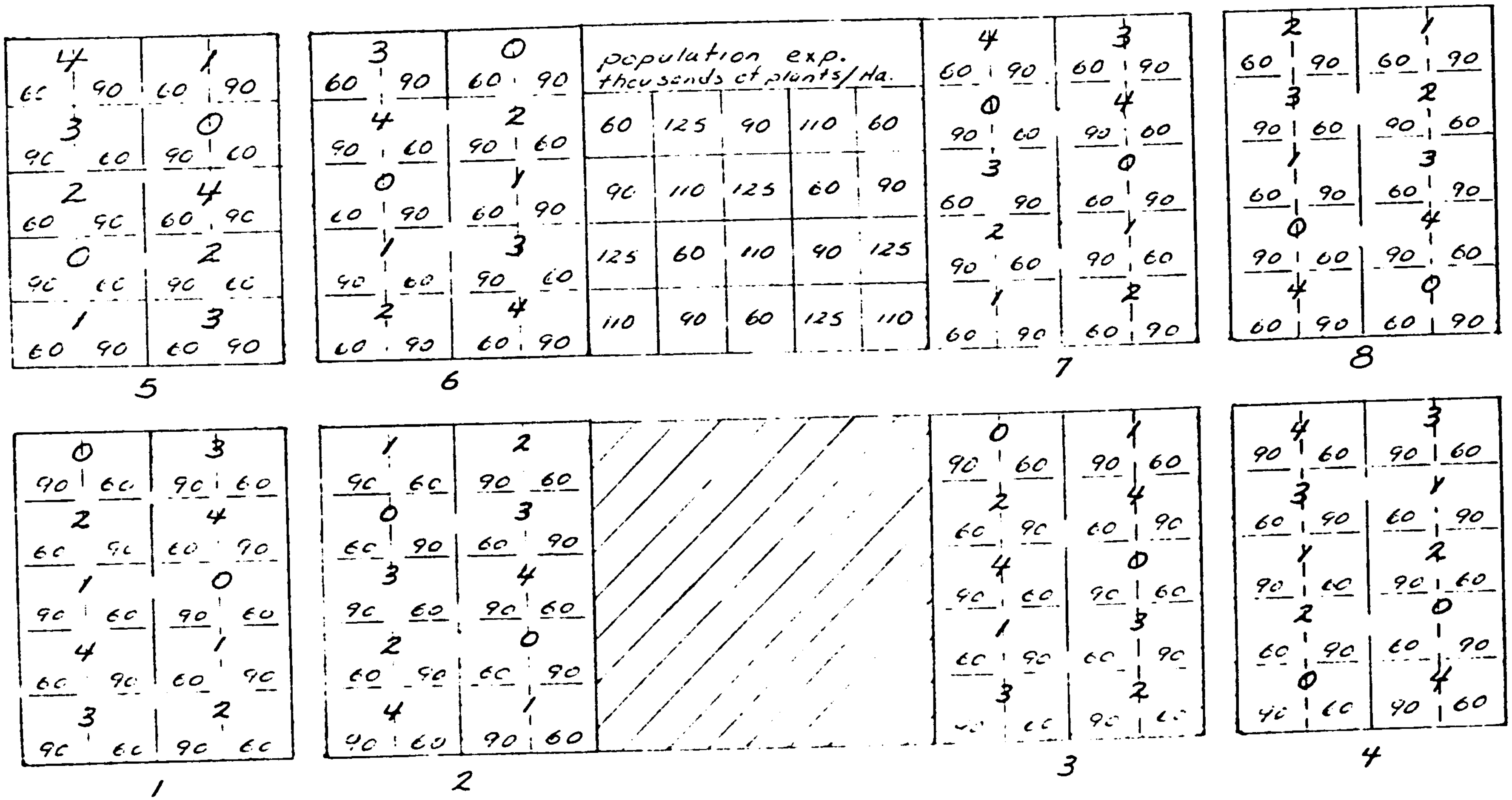


Figure I.1. Experimental Plan for Interaction Investigation and Population Experiment, Fundo El Castillo, 1970-71

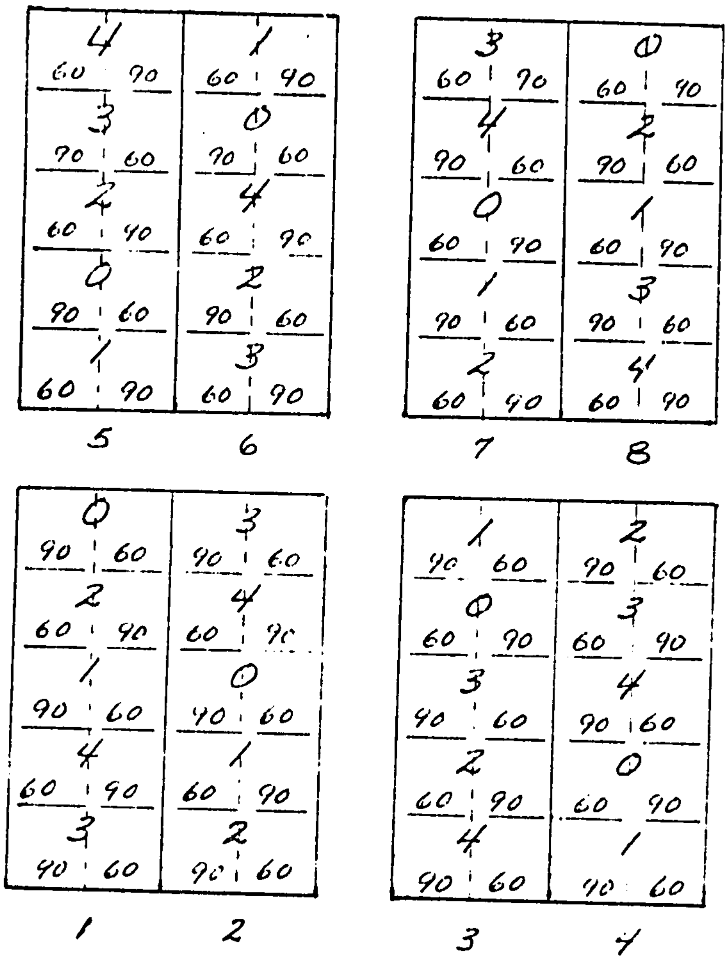
Nitrogen Rates:

0 - 0
1 - 100 kg/Ha.
2 - 200
3 - 300
4 - 400

Population:

60 - 60,000 plants per hectare
90 - 90,000 plants per hectare

Blocks 1, 3, 6, 8 - high soil moisture
Blocks 2, 4, 5, 7 - low soil moisture



Improved
Seed Bed

Normal
Seed Bed

Figure I. 2. Experimental Plan for Interaction Investigation, Fundo Condoroma 1970-71

PART II: Farmer cooperator experiments demonstrating production management techniques for improved corn production on commercial farms.

Objectives: (1) To demonstrate soil and water management and cropping techniques that are proven by the interaction experiments.

(2) To train extension personnel in designing, conducting, and in applying field demonstration-type experiments.

(3) To evaluate fertility conditions in commercial fields by comparing the yield of corn on plots receiving three levels of nitrogen fertilizer.

Procedure

Eight locations were selected in the Aconcagua valley near San Felipe and Los Andes, Chile. These included four cooperative farms (asentamientos), three private farms and one agricultural school. The chosen sites represented a variety of soil conditions. The locations were:

Agricultural School:	San Felipe	
Asentamientos:	Cristo Redentor	- Los Andes
	Vencedores Unidos	- Los Andes
	Tartaro de la Vicuna	- Putaendo
	El Nilhue	- Catemu

Farms:	Arturo Manzur	- Panquehue
	Federico Hardy	- Panquehue
	Sociedad Agricola Colonia	- Santa Maria

Variables in this project were irrigation methods and nitrogen fertilizer rate. The design was a "demonstrative block" with the two irrigation methods parallel and adjacent to each other. At right angles to the irrigation treatments, and continuous across them, were three rates of nitrogen fertilizer.

The nitrogen treatments were randomized. The nitrogen source was urea, and this was applied in rates of zero, 100, and 200 kilograms of the element per hectare. Method of fertilizer application was hand broadcast at the time of seed bed preparation. Field layout of the treatments is shown in Figure II. 1. There were no replications but the same general "block" was used at all locations. The "block" was about 60 meters by 100 meters in overall dimensions.

The first irrigation method, "tendido" is standard in the area. It consists of a modified border-flood irrigation procedure. Characteristically this method results in somewhat arbitrary irrigation intervals and non-uniform application. The second method of irrigation was by furrows with water applied to individual furrows through siphon tubes. Irrigation frequencies on the flood irrigation treatments were left to the discretion of the farmers. On the furrowed plots two tensiometers were installed in the soil at about 30 cm depth, at each location, and these plots were generally irrigated when the tensiometers were in the .6 to .8 atm range. Water applied by both methods of irrigation was estimated by measuring inflow and outflow with 90° "V" notch weirs.

In general the land was prepared by disc-plowing prior to planting. On the half block to be irrigated by furrows, and in some cases on the other half as well, at the insistance of the farmer, the land was spike-tooth harrowed to give a finer seed bed.

Seeding was done by machine using Chilean hybrid variety MA-7, attempting to approximate a population of 60,000 plants per hectare. Average plant densities varied among locations, from a low of 45,000 to a high of 78,000 plants per hectare.

Harvest technique consisted of selecting 16 rows each 15 meters long in the center of each of the six plots at each site. The ears were taken from every other row resulting in eight rows that were actually sampled for yield. The corn was weighed from each harvested row, the ears were counted and a subsample was taken to estimate moisture content of the kernels. Yields are expressed in terms of shelled corn at 15% moisture per hectare.

Results and Discussion

Table II.1 gives the results of the demonstration experiments at the eight locations. The results are shown in two groups: the four asentamientos in one group and the three private farms plus the agriculture school in the other. There is no distinction between the two groups in terms of corn yields. Overall yield means for each treatment are also shown in Figure II. 2 with the average cost of production and the gross value of corn produced as a function of nitrogen fertilizer rates. Table II. 3 shows cost of production figures which were prepared by the San Felipe area office of SAG representing average cost figures for the area.

Following emergence of corn in each of the 8 locations, plant population was estimated by actual field counts projected by calculation to population density per hectare. From this there is an apparent trend toward decreased number of ears of corn per plant as populations exceed 60, 000 and an increase in number of ears of corn per plant in population below 60, 000 (See Table II. 2.).

Yield differences between the two different types of seed-bed preparation coupled with the two different methods of irrigation were small and in favor of the methods normally practiced in the area. This can partly be attributed to three observations: (1) the cooperators tended to irrigate their plots when the furrow plots were irrigated; (2) the first furrow irrigation in some plots reduced the availability of nitrogen to a very noticeable degree indicated by a change of color of the plants to a lighter green than was maintained on the flood irrigated plots, especially in connection with plots with shallow, gravelly soil; and (3) the seed-bed prepared with the spike-tooth harrow to assist in the conservation of soil moisture in general gave higher plant emergence, resulting in plant densities which were apparently above that to which variety MA-7 is best adapted.

The overall average yield of corn at the 0-nitrogen rate was 43.19 quintales per hectare, at the 100-N rate 74.41 and at 200-N rate 88.36. At the El Castillo and the Condoroma experiments where there were no significant differences in yields between nitrogen rates, the averages through nitrogen treatments from the best cultural practices were 125 and 106 quintales per hectare, respectively. This indicates that there is still a possible potential increase in yields to be obtained from improved cultural practices.

The response of corn plants in growth and color to nitrogen at 100 kilos per hectare was observed to be demonstrative at all of the eight locations. The response from 200 kilos per hectare was observed to be demonstrative at 6 of the 8 locations. The yields from these locations show these differences (See Table II. 1.).

There was a marked increase in yield due to applied nitrogen as demonstrated in Figure II. 2. When these increases are compared to the average yield of corn for the Aconcagua province they become economically significant. The average yield of corn for Aconcagua according to SAG estimates is about 45 quintales per hectare (this figure is close to the average yield of the plots of the 0-Nitrogen rate of 43.97 quintales). When the low cost of production E^{o} 4.251.00 per hectare with no nitrogen (Table II. 3) is compared to the value of the corn at E^{o} 100.00 per quintal (approximate price paid for corn in 1971), a more or less break-even point is reached, E^o 4,500.00. This indicates that the additional production achieved by applying nitrogen fertilizer is the main area of profit available to the grower. When the average yields from the eight experiments are projected at the 100 kilo of N per hectare rate, this profit becomes E^o 2.816.00 per hectare, and at 200 kilos of N per hectare rate, E^o3.883.00 per hectare (Table II.4). When these same averages are projected on the basis of the total hectares of corn produced in Aconcagua province in 1971 (a total of 2,410 hectares) at the 100-N rate, there is the potential increase in yield of 64 percent with a profit of E^o 6,786.546, and at the 200-N rate there is the potential increase in yield of 96 percent with a profit of E^o 9,358.030 (Table II.5). Although not mentioned in the above discussion on increases and potential increases in yields of corn, the improved culture practices which were included as part of these experiments, mainly seed-bed preparation and water management contribute to the increased production. Considering the higher corn yields at the El Castillo and Condoroma experiments where culture practices were more carefully controlled, an even greater potential for the Aconcagua area is possible (See Table II.5.).

During the realization of the eight demonstration experiments, various professional and technical people were trained. During the planning and organization two agronomy engineers of the Agricultural and Livestock

Service (SAG) and one from the Agriculture Research Institute (IIA) were involved. These people also cooperated later in the execution of these experiments in the field.

The carrying out of this project in the field was done by two agricultural technicians, two agricultural aides and one student in agriculture technology of SAG.

The training received by these people was in all phases of corn production, including the following:

a) Land preparation: A seed bed prepared for a manner to conserve soil moisture was compared to the type usually prepared by the farmer. Some implements for seed bed preparation were introduced which are not normally used in the country.

b) Fertility: The effects of different rates of application of nitrogen fertilizer were compared. These effects were observed in the appearance of the crops during the growing season as well as in the grain yield at harvest time.

c) Planting: The effect of a higher plant density than that generally used by the farmer could be observed. The calibration and use of the different makes of planters provided very good training.

d) Irrigation: Uniformity of irrigation by use of furrows and siphon tubes was compared to non-uniformity of irrigation by flooding. Water applied was measured using triangular weirs. Tensiometers were used to determine irrigation frequencies. All of this constituted good training in the installation, use and maintenance of this equipment.

e) Cultivation: The regulation, adjustment, and use of cultivating equipment owned by the farmers provided some useful training for the technicians.

f) Harvest: The harvesting of the plots provided training and experience in estimating crop yields. It also provided training in the use of moisture meters.

The experience gained from these various phases of production have been a means of helping the professional people, and the technicians involved, to understand the value of using demonstrative experiments in teaching improved practices to farmers. It has also helped them to recognize the value of demonstration experiments in obtaining additional useful information.

Carrying out these eight demonstration experiments also provided some direct training to the farmers who collaborated in and personally participated in the work. Their experience helped them to recognize that many of the practices involved are adaptable to other crops as well as corn.

During the course of these experiments they were visited by the President's representative in the province; authorities and technical personnel of SAG, IIA, CORA, Agricultural Development Institute, University of Chile, Catholic University of Valparaiso and members of the AID mission to Chile. Also, several groups of farmers visited the sites in tours conducted by SAG.

Summary and Conclusions

In the area of Los Andes and San Felipe in the Aconcagua valley, demonstration experiments with three nitrogen fertilizer levels and two irrigation methods using MA-7 variety of corn were conducted at eight locations.

The results indicated a marked increase in corn yields with increase in nitrogen fertilizer applied, with very little difference between irrigation methods. The results also indicate that corn production in this area could be increased by nearly 100 percent.

Training was given to several technicians in the use of demonstrative experiments as a means of extending improved farm practices and gathering information.

The following conclusions were drawn from the results of these experiments:

1. Seasonal nitrogen carryover in the soil is an important factor governing the need for nitrogen fertilizer. Future experiments should include a method of sampling and analyzing soils for available nitrogen in order to obtain a correlation between soil nitrogen availability and crop nitrogen requirements.

2. Best soil management practices from the point of view of irrigation were not evident in the results. Specific research on the soil factors that influence water conductivity and water availability is needed.

3. The results to date are inconclusive both as to the optimum plant population density and specific corn variety. There is probably a need for more corn hybrid development in Chile in order to obtain varieties that are specifically adapted to intensive irrigated agriculture.

4. The data and experience gained in this research project provide some very important prerequisites for the proper design and execution of future experiments that have as their objective the development of corn yield response functions.

Table II. 1. Yield of Shelled Corn at Standard 15% Moisture in Quintales per Hectare for Demonstration Experiments

Location	Furrow Irrigated Kgs. N per hectare			Flood Irrigated Kgs. N per hectare		
	0	100	200	0	100	200
C. Redentor	42.16	57.44	121.41	55.42	77.67	91.77
Vicuna	79.08	108.40	101.39	52.89	57.08	40.61
Vencedores	57.87	54.42	87.30	53.93	89.05	103.80
Nilhue	25.45	38.14	58.59	45.61	77.30	63.81
Total	204.56	258.40	368.69	207.94	301.10	299.99
Average	51.14	64.60	92.17	51.98	75.27	75.00
Escuela Ag.	13.94	71.60	66.89	14.53	86.16	114.33
Hardy	32.12	76.62	109.81	48.83	77.32	101.87
Manzur	16.93	50.31	69.71	29.56	66.03	82.68
Colonia	75.80	87.66	75.60	59.37	117.33	124.16
Total	138.79	286.19	322.01	152.29	346.84	423.04
Average	34.70	71.55	80.50	38.07	86.71	105.76
Overall Total	343.35	544.59	690.70	360.23	647.94	723.03
Overall Average	42.92	68.07	86.34	45.03	80.99	90.38

Combined Average Yields

	0 - N	100 - N	200 - N
Furrow Irrigated	343.35	544.59	690.70
Flood Irrigated	360.23	647.94	723.03
Total	703.58	1.192.53	1.413.73
Average	43.97	74.41	88.36

Table II.2. Estimated Plant Population at Emergence and Harvest of Corn Variety MA-7

Location	Furrow Irrigated		Flood Irrigated	
	At Emergence	At Harvest	At Emergence	At Harvest
Nilhue	61,300	56,894	51,500	57,804
Escuela Ag.	45,000	49,246	62,800	47,589
Colonia	60,000	57,632	54,000	57,060
Manzur	68,800	61,142	59,550	58,182
C. Redentor	75,000	67,514	78,150	70,236
Vicuna	77,000	69,793	59,600	57,219
Hardy	69,000	65,412	65,000	69,657
Vencedores	74,300	60,762	64,500	56,479
Average:	66,300	61,049	62,000	59,278

Table II.3. Corn Production Costs per Hectare

Item	Days Man	Days Tractor	Cost
Field clearing	2.9	-	E° 88.16
Plowing	1.4	1.4	602.56
Discing	1.4	1.4	602.56
Canal cleaning	0.5	-	15.20
Ditching	0.3	0.3	129.12
Pre-irrigation	2.0	-	60.80
Planting	0.3	0.3	129.12
Fertilizer application	0.7	-	21.28
Hand weeding and cultivation	9.2	1.0	439.68
Irrigation	13.7	-	416.48
Hand harvesting	27.5	-	836.00
Hauling	2.3	-	69.92
Handling, storage	2.0	-	60.80
Total			E° 3,471.68

Cost per man-day: E° 30.40

Cost per tractor-day with implements: E° 400.00

Insumos:	30 kilos seed at E° 12 per kilo	E° 360.00
	4 kilos aldrin 40% at E° 35 p/kg	140.00
	200 kilos superphosphate at E° 1.40	280.00
	Total	E° 780.00
	Nitrogen (salitre)	
	100 units 666 kilos	E° 575.42
	200 units 1,333 kilos	1,151.71
	Nitrogen (urea)	
	100 units 222 kilos	E° 333.00
	200 units 444 kilos	666.00

Price of harvested corn: E° 100.00 per quintal

Table II.4. Projected Production and Cost Figures per Hectare Based on Average Yields of the Demonstration Experiments

Nitrogen (kg.)	Yield (qq.)	Percent Increase	Gross E^o	Cost E^o	Net E^o
0	44	-	4,400	4,251	149
100	74	68	7,400	4,584	2,816
200	88	100	8,800	4,917	3,883

Table II.5 - Projected Potential Production Figures for the Aconcagua Province Based on Demonstration Experiment Results*

Description	Yield In Quintales	% Increase In Yield	Net Value E^o
Average for Aconcagua Province	108,450	-	600,090
0 N	106,040	-0.2	359,090
100 kg. N/Ha.	178,340	64.0	6,786,560
200 kg. N/Ha.	212,080	96.0	9,358,030
Condoroma 106 qq/Ha.	255,460	135.0	13,696,030
El Castillo 125 qq/Ha.	301,250	178.0	18,275,030

* Totals based on the 2,410 Ha. of corn planted in the Aconcagua Province in 1971.

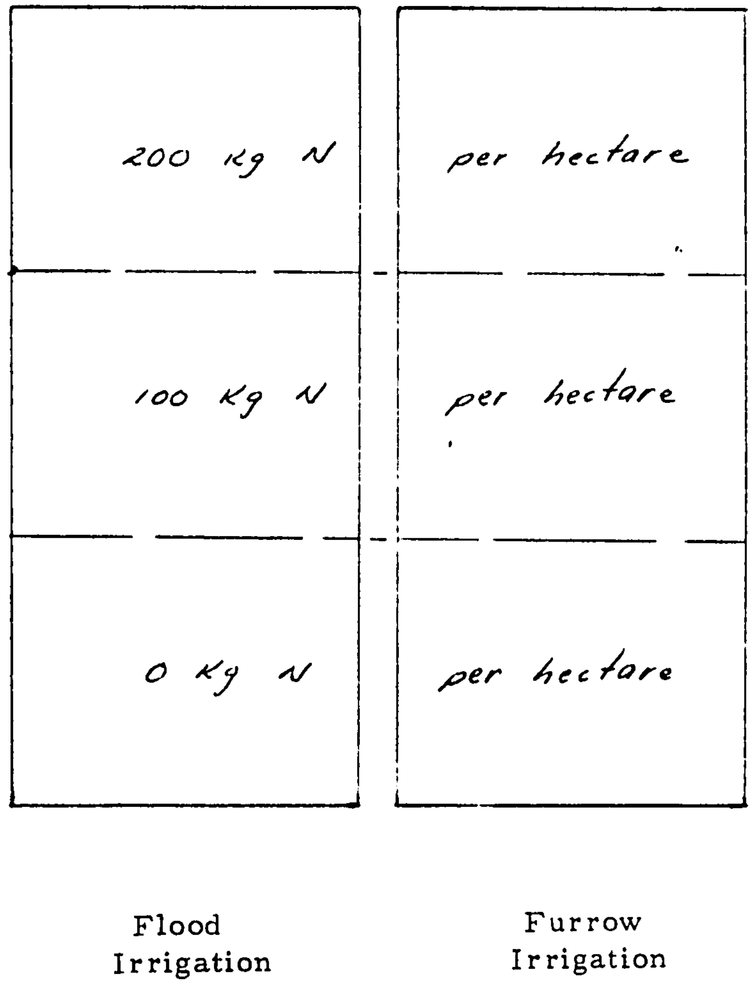


Figure II. 1. Field Layout of Treatments in Demonstrative Block

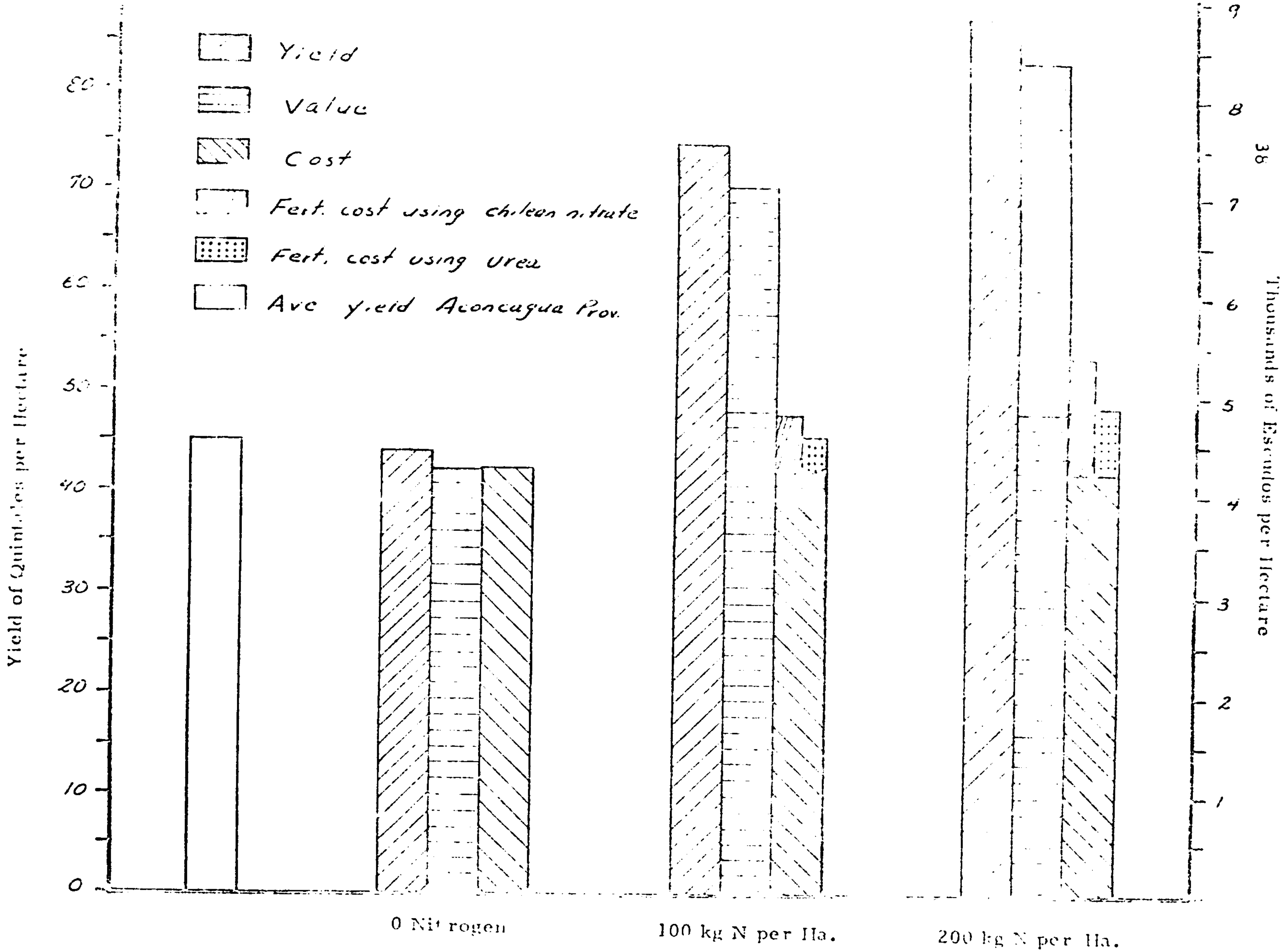


Figure II. 2. Average Yields for Eight Demonstrative Experiments with Production Costs and Gross Value of Corn Produced

PART III: Plant population experiment in corn.

Objective: To study the effect of plant population on corn yields using corn hybrid MA-7.

Procedure

This experiment was adjacent to the water-fertilizer-population experiment at the El Castillo site. The procedure for this experiment was the same as those already discussed (see Part I above) except for the following items: (1) the nitrogen fertilizer was applied uniformly at the rate of 200 kilos per hectare by spreading the fertilizer directly into the irrigation furrow just prior to the first irrigation; (2) plant populations were established in a randomized complete design in five replications with the following population densities: 60,000, 90,000, 110,000, and 125,000 plants per hectare.

Results and Discussion

Tables III.1 and III.2 give the results of this experiment.

Table III.1 shows the average yield in kilograms per row of shelled corn at standard 15% moisture content row.

Table III.2 shows the average number of ears of corn per hectare (averaged across replications) which resulted from the four populations. In addition it shows the quintales per hectare yield of corn at standard

15% moisture content. Statistical analysis of the yield data is given in Table III. 2.

The yield results are shown graphically in Figure III. 4.

Corn yield decreased almost linearly from the lowest to the highest plant population. There may be a yield maximum above or below 60, 000 plants, but taking these results in connection with those already given for Part I above, it is obvious that the yield maximum is below 90, 000 plants per hectare.

The average number of ears per plant was slightly greater than 1 with the lowest plant density. This statistic decreased with higher populations to an average of about 0. 8 ear per plant with the highest population. It is obvious also that the average weight of corn per ear decreased sharply with increasing plant density.

As stated in connection with Part I above, there is considerable contrast between variety MA-7 and the variety used the previous season (Tracy-133). It was observed that MA-7 has the ability of putting out several secondary shoots, or succers, and that these shoots can develop marketable corn. It is apparent that this characteristic provides MA-7 with the ability of adjusting at low population densities and, therefore, to overcome, in some degree, the effects of poor stands. For this reason it may be an important variety to Chile under the existing conditions of low management intensity.

It would seem advisable to collect more information as to the ability of MA-7 to perform under average field conditions in comparison to other varieties used by Chilean farmers. MA-7 should also be more thoroughly evaluated in comparison with other varieties under conditions of intensive irrigated agriculture.

Summary and Conclusions

An experiment was conducted near Los Andes, Chile to evaluate the effect of plant population density on yield of shelled corn. One variety was used---Chilean hybrid MA-7. Four plant populations were tested ranging from a low near 60,000 plants per hectare to a high of about 125,000 plants per hectare.

Yield of shelled corn decreased continuously from the lowest to the highest plant density. Average numbers of ears per plant also decreased regularly with increasing population. These results contrast sharply with those obtained previously using another variety.

MA-7 is probably well adapted to low intensity crop management because of its apparent ability to adjust to low stands which could result from poor seedling establishment conditions.

All results taken together emphasize the importance of evaluating corn varieties to maximize corn yield under conditions of intensive irrigated agriculture.

Table III. 1. Yield of Shelled Corn at Standard 15% Moisture Population Experiment El Castillo in kg/row

Population	Replication					Total
	1	2	3	4	5	
60,000	9.64	9.35	9.60	9.37	8.04	46.00
90,000	6.41	5.41	6.04	5.78	7.05	30.69
110,000	5.10	6.35	6.12	4.64	5.61	27.82
125,000	4.42	5.05	4.63	4.82	4.97	23.89
TOTAL	25.57	26.16	26.39	24.61	25.67	128.40

Table III. 2. Average Number of Ears and Yield of Shelled Corn at 15% Moisture Content for Population Experiment at El Castillo

Population Plants/Ha.	Number of Ears per Ha.	Average Yield qq/Ha.
60,000	67,000	133.0
90,000	92,000	88.0
110,000	99,400	80.0
125,000	106,100	68.5

Table III. 3. Analysis of Variance for Yield Data, Population Experiment

Source	df	ss	MA	F
Total	19	61.77		
Reps	4	.47		
Population	3	56.18	18.73	43.56 **
Error	12	5.12	.43	

** Significant at 1% level.

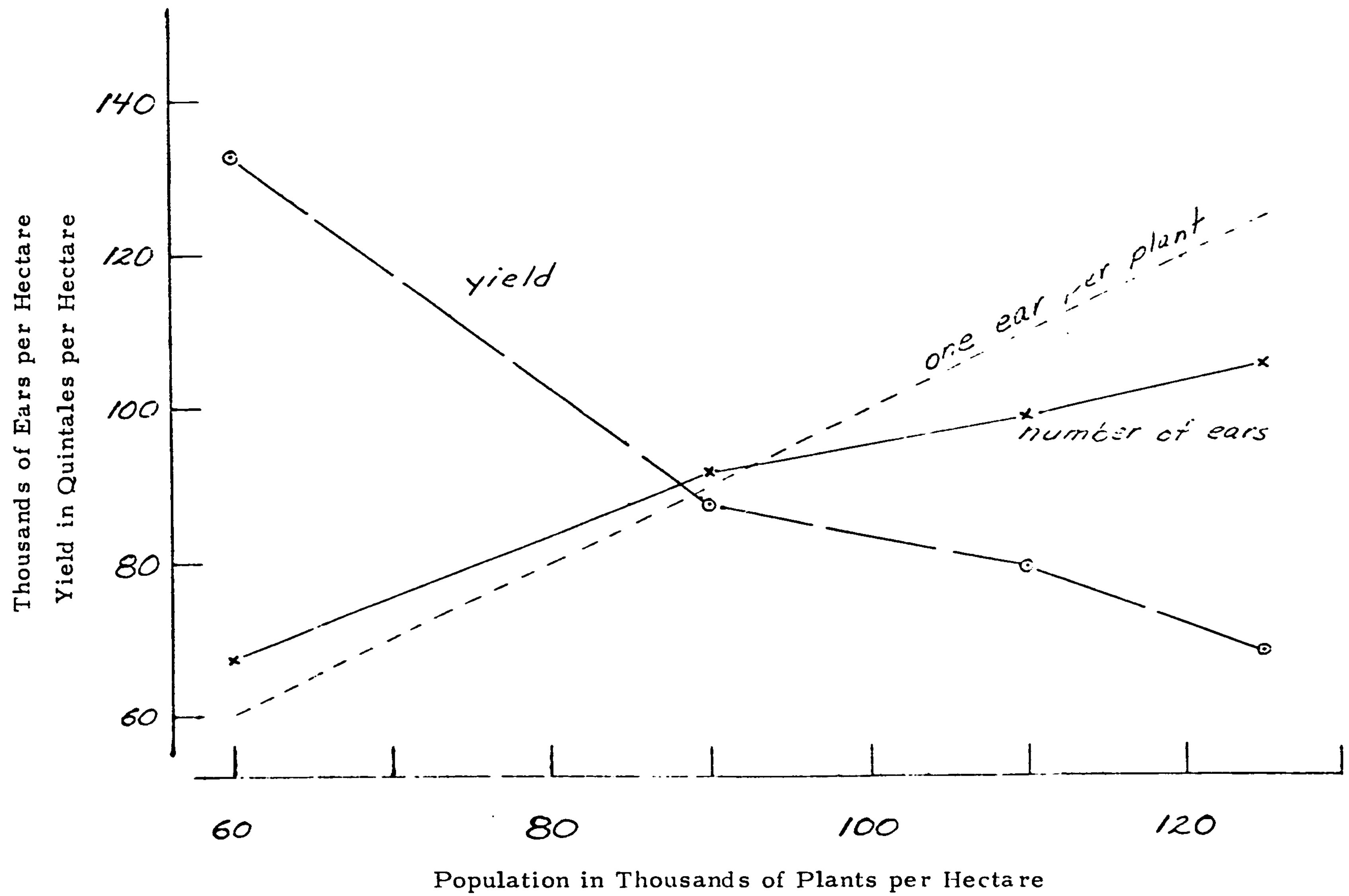


Figure III. 1. Number of Ears and Yield of Corn for Different Plant Populations