# SORGHUM IN CENTRAL AND SOUTH AMERICA

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## INTRODUCTION

Drs. Vartan Guiragossian and L.R. House have had the opportunity of several trips into Latin America to learn about sorghum. We have been aware that ICRISAT is considering the possibility of developing one or more regional centers in the America's and have made suggestions to this end.

Information has come from several visits, different papers, and the International Sorghum Meeting in Buenos Aires. Information is ramified and detailed. This report is broken into a number of statements, the first two are summary in nature and include our recommendations. Other sections and reports are included because they present an array of information in such a way that one reading them can better form his own opinion and hopefully respond with more confidence to an ICRISAT approach to the Americas.

This is presented as a statement useful in formulating proposals for funding. We would be happy to contribute further to the development and strengthening of an ICRISAT presence in the America's should the opportunity arise.

L.R. HOUSE & VARTAN GUIRAGOSSIAN

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# SOME GENERAL COMMENTS AND RECOMMENDATIONS FOR ICRISAT ABOUT SORGHUM IN LATIN AMERICA

Sorghums are widely grown in Latin America. The rate of increased area sown and rise in yield is higher in this area than in any other part of the world - increases have been spectacular in Mexico and Argentina.

These increases have come largely in response to increasing demand for animal feed. Large productive agricultural areas were available employing modern farming techniques. Seed companies from the USA were attracted into the area and now many Latin companies have develop working with both corn and sorghum. The thrust in research and development has been directed toward the larger farmer capable of substantial production. Research and development for the needs of the poorer more subsistance type farmer has largely been ignored (See APPENDIX III).

Sorghum is or could be used in essentially three broad ecological regions that would benefit the poorer farmer. The drier areas such as North-East Brazil where rainfall is highly variable and drought common. In high rainfall areas where periods of drought are realized during the growing season, fields frequently are rolling to steep so run off is high, water penetration is poor and the soils have a low water holding capacity. Such situations are typical of much of Central America. The third region consists of the higher elevation areas where both high and low rainfall situations exist. Concern by ICRISAT for sorghum improvement has been centered in the extensive higher elevation droughty areas of Mexico involving approximately 1.3 million hectares of land. There are indications that materials developed there are also beginning to find places in new higher elevation areas in other Central American countries (around 1800-2000 meters). Aside from the research efforts for the development of sorghums for the higher elevation areas very little research is being done for these more marginal growing conditions. ICRISAT would find a challenging opportunity.

The first sorghums used in the Latin countries came from the USA and a common conception has developed that most of the sorghums used are from there. Today, in places like Argentina only about 20% of the sorghum grown was bred in the USA - the rest comes from local research. However, it is true that the origin of most of the material is from the USA. US developed material falls off in productivity in the more tropical regions - the availability of good A-lines (seed parents for hybrids) from the US are frequently so poor that seed production would not be economical. Also, as US developed materials become less productive, to a degree, interest drops off, numbers of companies decrease, and the input into research is less. It seems evident that ICRISAT need not be concerned about sorghum improvement in more temperate areas where research input already rests on the

vast investment in the USA and the one rapidly developing in some of the more temperate Latin countries. However, ICRISAT might well contribute in the more the tropical areas where they have greater experience, access, and knowledge about sorghums than exists in the USA.

Dr. Vartan Guiragossian and I have had some opportunity to visit and appraise the sorghum position in a number of Central and South American countries We both feel strongly that ICRISAT should have a presence in the Americas. This has been supported by a resolution of the conference in Buenos Aires and by a warm invitation on the part of several prominent sorghum workers in the region (See APPENDIX V). Dr. Richelli from Venezuela, Dr. Torrigroso from Colombia, and Dr. Carballo Aquiles from Mexico all made a special point to talk about a regional center of ICRISAT in their country or at least in the Americas. We recommend that ICRISAT establish two regional centers in the Americas; one in Brazil in the North-East and one at CIMMYT in Mexico. A suggestion was also made by Dr. Shaffert, coordinator for sorghum in EMBRAPA, that ICRISAT consider establishing at the National Corn and Sorghum Center at Sete Lagoas. This possibility can be further evaluated.

A research opportunity in the North-East of Brazil would enable us to undertake varietal development in the semi-arid situation. Pay off could be in terms of a more stable food type sorghum for the poorer farmer and in terms of mechanized production on large holdings to help solve the problem of 4 to 5 million tons deficit annually in cereal grains in this region.

An ICRISAT center in the North-East might be at Caruaru or Racife. Caruaru is about 2 hours drive from Racife and in a semi-arid region. However, the IPA station there is poor and it may be necessary to find better land and water. The three stations of Caruaru, Serra Talhada, and Araripina in Pernambuco State would all be useful. If a man were stationed in Racife he could likely have use of land at the University where intensive crossing activities could be undertaken. This would also be a useful site for an off-season nursery. The ICRISAT man would likely coordinate sorghum research in the North-East but should be a contributing member to the EMBRAPA country wide program. He would also have regional responsibilities. Beside an input into the development of varieties and hybrids for the North-East ICRISAT could contribute by introduction and evaluation of collections and elite stocks of Indian and African origin on the acid, aluminium toxic, low fertility soils of the Cerrado area.

We seriously considered CIAT or CIMMYT as a place to center and finally decided to recommend CIMMYT. The opportuntiy to use the various climatic situations in Mexico within relatively short distance is attractive. Another important aspect was the ease with which material developed at somewhat higher latitudes will move to lower latitudes but that the reverse is not true. We do know that entries

from Serere in Uganda do not contribute well when moved much more than 9 to 10 degrees latitude. It seems reasonable to extrapolate this experience to the Americas Dr. Angel Salazar, working with Dekalb in Nicaragua mentioned to Vartar that sorghums received from Colombia were not adapted. Many of the disease and insect problems of the region are found in Mexico so breeding against them is possible.

We feel that the current program centered at CIMMYT should be modified substantially so that about 80% of the effort would be focussed on low and mid-elevations and about 20% on higher elevation material. This would enable us to place a major thrust where sorghum is now grown and a minor thrust in the more exploratory high elevation situation. We feel strengthened in this division of priority because of the strong programs to develop sorghums for the high elevations by the national program (INIA) and by the University of Chapingo. Alexander Grobman suggested to Vartan that the best solution would be to place a man at CIMMYT and at CIAT. An assistant of Dr. Torregroso, working in Colombia, made the comment that maize developed at Poza Rica did very well in the lowlands of Colombia. However, in the high elevations, corn varieties from CIMMYT do not fit - they are not early enough. On the other hand the corn varieties from the high elevations of Colombia are late in Mexico. To solve this problem CIMMYT has established cooperative work in corn centered in Equador to help the highlands of Bolivia, Peru, Equador, and Colombia. Possibly at some future date based on greater experience in the area, ICRISAT may wish to consider something similar.

Dr. E.W. Sprague again reiterated that CIMMYT could provide the ICRISAT program a total 10 hectares a year divided across seasons and locations (El-Batan, Tlatizipan, and Poza Rica). Dr. Carballo Aquiles, sorghum coordinator for INIA, expressed interest in the presence of ICRISAT in Mexico and indicated that there is a large INIA station (Zakatepek) that could be used by ICRISAT if more area is required in the lowland tropics. This station is a bit further from El-Batan than Poza Rica (more to the south).

We also felt some value in this proposal in that a certain amount of training could be undertaken in both Spanish and Portugese speaking areas.

Another interesting contribution that ICRISAT could make from CIMMYT is assistance with the coordination of the sorghum program of the PCCMCA.

The PCCMCA is an unofficial informal group of plant scientists for the six Central American countires, Guatemala El Salvador, Honduras, Nicaragua, Costa Rico, and Panama. It began some 25 years ago on corn and has expanded to include sorghum, beans, rice and root crops.

They hold an annual meeting attended by some 300 scientists from government and private companies. Papers are presented and the meeting breaks into work groups to review past work and organize regional trials. The meeting is rotated between countries and is financed by the host country. They have no office and no permanent staff. Seeds for the regional trial are gathered by one person and organized into trials. The data is accumulated and organized into a report.

At the present time CIMMYT staff are coordinating for the corn program as they have facilities to put up the seed, visit the trials, accumulate the data and use their computer to analyze data and organize the report. They have not been able to do this for sorghum and usually a report is not organized. Vartan was frequently approached, while travelling in Central America, for ICRISAT to provide this same coordination function for sorghum as CIMMYT is doing for maize. This function while worthwhile and something for which ICRISAT could contribute, is of such a magnitude that ICRISAT would have to consider this in its support staff structure.

If ICRISAT should place a man in North-East Brazil there has been a repeated request that he be involved with the coordination of sorghum improvement work in cooperation with EMBRAPA in the four states of that area.

## ICRISAT's Potential Research Involvement in the Americas

### General

It has been proposed that ICRISAT establish two regional centers in the Americas, one in cooperation with CIMMYT, IMIA and the University of Chapingo, and the other, in North-Eastern Brazil at an IPA station through EMBRAPA. In due course, with more experience, the possibility of a third location in cooperation with CIAT might be considered.

Initially at least, one plant breeder for only sorghum should be stationed at each of these locations. The insect and disease situations are of considerable concern and thought might be given at the outset to placing a pathologist with the station at CIMMYT and an entomologist in North-Eastern Brazil. A good research technician would also be required at the CIMMYT location if ICRISAT were to help with coordination of the PCCMCA activities in Central America.

A great interest was expressed at the International Sorghum meeting in Argentina about the documentation service that ICRISAT will provide. I was requested to give a 10 minute talk about the Sorghum and Millets Information Center. Interest was expressed in the possibility of translation into Spanish and Portugese.

Tremendous interest was also expressed in the training program of ICRISAT. This interest included training at the Center in Hyderabad and in inservice training at potential regional stations in the Americas where instruction could be in Portugese and Spanish.

Sorghum, in most of the places where it is used by the poorer, smaller farmer, is sown with corn and beans. Only, on large mechanised farms is it a single crop. As part of its potential program thrust to assist the poor farmer, cropping systems will be important. Cropping systems is apt to be an aspect of ICRISAT's input into Brazil and the sorghum breeder should cooperate with this effort. This will be an important concept in many of our possible activities in the Americas.

There is a need for economic input. Sorghum has moved more rapidly into areas where economic policy has been encouraging. It would appear that opening up of the North-East of Brazil to the type of production that would solve their 4-5 million ton annual import into that region will require sound economic planning if it is to succeed.

There is a certain value in communication if ICRISAT has regional centers in the Americas. There is a tendency to come more directly into ICRISAT's flow of materials and fit better, more efficiently, as part of an ICRISAT global network. It is difficult to appraise this value but surely it would result in a speed up - greater efficiency - of crop improvement.

A regional opportunity will permit periodic visits to sorghum stations in other countries. This helps hasten the exchange of useful breeding materials and ideas. This would be an important contribution of ICRISAT to the region.

Sorghum Breeding

The potential input of ICRISAT into breeding activities have several rather distinct aspects.

The food type sorghum varieties used in Central America are very late. It may not be possible or even desirable to eliminate photoperiod sensitivity but varieties maturing about one month earlier than the locals would appear valuable for most of the Central American countries. This project would be centered at the ICRISAT regional station at CIMMYT.

An input is still required, particularly to develop good food type sorghums, for the high elevation areas of Mexico and other Latin countries. More extensive evaluation of materials now in the program should be made in the 1500-2000 meter elevation range in Mexico and other countries (Central America, Colombia and Equador). (This program could be associated with ICRISAT-CIMMYT).

The very acid, aluminum toxic soils of the Cerrado include a large land area of Brazil but are also of importance in Venezuela and Colombia. There are already indications of useful variation in sorghum to susceptibility to this soil condition but only a portion of the total variation has been evaluated for its reaction. It would seem useful if ICRISAT would cooperate in evaluating the world sorghum collection and useful agronomic types from India and Africa on these soils. This work could be undertaken in cooperation with the EMBRAPA program at Sete Lagoas.

The need for varieties well adapted to the tropical Americas is a general problem. Much of the available germplasm in use has originated from the USA and its adaptation declines in more tropical areas, also the varietal sources from the USA are poor in food quality and while the major interest for sorghum is for animal feed, there is rising interest in food use.

There is a strong tendency for the use of hybrids throughout the Latin area. Two problems have been realized in attempts to use and produce hybrids developed in the USA. Seed parents (A-lines) are poorly adapted and hence it is difficult to produce economically satisfactory yields of seed; and, second, hybrids that nick (syncronous flowering of male and female parents) in the production yields in the USA fail to do so in more tropical areas and so, again, fields are low and the possibility of contamination from stray pollen is high. This was mentioned as a problem in Colombia. Not only in the Americas, but elsewhere, it seems important

for ICRISAT to become involved in the development of parents for hybrids with particular emphasis on tropically adapted A-lines.

Insect and disease problems and resistance to drought are important problems in which ICRISAT breeders in the Americas should be cooperatively associated. This is mentioned in greater detail below.

Drought resistance

Sorghum has undergone a spectacular increase in use in the Americas in the last 10-15 years primarily because it gives better more stable yields than corn in drier areas. Climatic data, can be misleading because sorghum is moving into areas where rainfall exceeds 1000 mm. These areas have sloping fields where runoff is high, water penetration is poor and there are thin soils with low water holding capacity. Breaks in the rain of a long enough time to cause drought stress are common. The problem was mentioned as one of major importance in limiting yield in Mexico, Guatemala, El Salvador, and Brazil (Cerrado Soils).

There is also the need for drought resistant types in areas where the expected total rainfall is low 350-700 mm.

The need for cooperation with ICRISAT's program for drought resistance is apparent.

Insect Pests

The insect pests mentioned to be of concern in Central and South America are:

| | |
|---|---|
| 1. Midge | Contarina sorghicola |
| 2. Sugar cane stalk borer | Diatraea lineolata |
| 3. Fall army worm | Spodoptera frugiperda |
| 4. Wire worm | Cusano alambre |
| 5. Green bug | Schizaphus graminum |
| 6. Webworm (Celama) | Pyroderces sp. |
| 7. | Agrotis ipsilon |
| 8. | Heliothis zea |
| 9. Chinch bug | |
| 10. Grain storage insects | |
| 11. | Elasmopalpus lignosellus |
| 12. Aphids | Rhopalosiphum maidis |

Without question, the major problem appears to be midge, but close seconds are the sugar cane stalk borer and the fall army worm. Elasmopalpus was devastating at the station at Araripina in the north west corner of Pernambuco state in Brazil, but otherwise, was seldom mentioned.

The green bug was mentioned as a problem in Mexico, Argentina, and Bolivia but not in the more tropical areas. It is likely that grain storage pests are wide spread but were mentioned only in Bolivia.

Approximate distribution of insect pests of concern on sorghum in Central and South America.

| Country | Midge | Sugar cane stalk borer | Fall army worm | Wire worm | Aphids | Green bug | Web worm | Agrostis ipsilon | Heliothis zea | Chinch bug | Grain storage pests | Elasmophalpus s |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mexico | x | x | x | | | | | | | | | |
| Guatemala | x | x | x | | | | | | | | | |
| El Salvador | x | x | x | | | | | | | | | |
| Nicaragua | x | x | x | | | | | | | | | |
| Colombia | x | x | x | | | | | | | | | |
| Venezuela | x | x | | | | | | | | | | |
| Brazil North | x | | | | | | | | | | | x |
| Brazil Central | x | x | | | | | | | | | x | |
| Bolivia | x | | x | | | | | | | | x | |
| Argentina | x | x | | | | | | | | | | |

Breeding for resistance to midge in varietal materials adapted to the more tropical Americas would appear to be of considerable importance. The problem is well expressed in North-Eastern Brazil and if ICRISAT establishes a regional station in this area breeding for resistance to this insect should constitute an important part of its program. Elasmopalpus lignosellus, while apparently restricted in importance to the North-East is serious and would also require further investigation. The sugar cane borer is present in Brazil, the fall army worm was not mentioned as a problem. These two insect pests appear to be severe enough in the Americas that it would be valuable to investigate the situation further to decide just what to do and from where to do it. If in Brazil, it would appear

that cooperation with the sorghum program of EMBRAPA at Sete Lagoas would be worthwhile. These two pests are not of importance in Asia and Africa so research would have to be undertaken in the Americas.

Green bug is a problem in the more temperate areas; this is an important problem in the USA and resistant lines have been developed there.

Diseases

The diseases that were mentioned to be of concern in Central and South America are:

| | |
|---|---|
| 1. Anthracnose | Colletotrichum graminicola |
| 2. Grey leaf spot | Cercospora sorghi |
| 3. Downy mildew | Sclerospora sorghi |
| 4. Zonate leaf spot | Gleocercospora sorghi |
| 5. Bacterial leaf strip | Pseudomonas andropogoni |
| 6. Charcoal rot | Macrophomina phaseoli |
| 7. Leaf blight | Helminosporium sorghicola |
| 8. Rust | Puccinia purpurea |
| 9. Grain moulds | |
| 10. Virus | |

The areas where these diseases occur vary, sometime within a country. Generally anthracnose is most wide spread; downy mildew is common, spreading, and of considerable concern; and head moulds are a common problem. The other diseases are frequently not of economic importance over broad areas; but, for example, virus is important in Venezuela.

An approximate distribution of diseases is as follows:

| Country | Anthracnose | Grey leaf spo | Downy mildew | Zonate leaf spot | Bacterial leaf strip | Charcoal rot | Leaf blight | Rust | Grain moulds | Vi |
|---|---|---|---|---|---|---|---|---|---|---|
| Mexico | x | | x | | | x | | | | |
| Guatemala | x | x | x | x | x | | | | x | |
| El. Salvador | x | x | x | x | | | x | | x | |
| Nicaragua | x | x | | | | x | | | x | |
| Colombia | x | | | | | x | x | x | x | x |
| Venezuela | x | | x | | | | | | x | x |
| Brazil North | | | | | | | | | | |
| Brazil Central | x | | | | | | | x | | |
| Bolivia | | | x | | | | | | | |
| Argentina | | | x | | | | | | | |

Anthracnose is wide spread and important and should constitute part of any ICRISAT program on sorghum improvement in the Americas. The disease was devastating around Sete Lagoas and in the Agro Industria Area of the San Francisco River Valley in Northern Minas Gerais. It was also mentioned to be important at Caruaru. Cooperation with the corn and sorghum center of EMBRAPA at Sete Lagoas would appear valuable also cooperation with Texas A & M and Purdue would be worthwhile as both of these institutions are working on this disease.

Downy mildew is a disease of importance and of increasing concern. It is more of a problem in Mexico than in Central and North-Eastern Brazil. This disease is readily observed at Poza Rica and could constitute part of the ICRISAT program if a regional center is established in cooperation with CIMMYT. Close cooperation with Texas A and M would be worthwhile.

An input into resistance to charcoal rot could be centered with the ICRISAT program at CIMMYT using materials from Texas A & M and ICRISAT., Hyderabad. Although not indicated, grain moulds develop well at Poza Rica in the summer. The ICRISAT program in Mexico could use source materials from Hyderabad to transfer resistance into locally adapted materials.

The importance of the other diseases would need further investigation before a recommendation might be made for ICRISAT involvement.

Food Uses of Sorghum

Sorghum is already used as a food in Central America.

In Guatemala, about 80% of the sorghum production is in association with corn and beans. About 64% of this production is for home use and of this 40-50% is used in tortillas. In El Salvador about 50% of the production goes into tortillas, about 8% of the production of Nicaragua goes into food, as tortillas and into a drink called Tiste. There apparently is a rising interest in the possible use of sorghum as a food in Colombia where there is a possibly a very limited use in soup, Arepa, and a fermented drink called Chicka. There is also a growing interest in using sorghum as a food source in the high elevation droughty areas of Mexico.

Sorghum flour is used in these countries to extend maize; sometime tortillas are made of flour one half corn and one half sorghum. Almost all co ntries of the South American region extend wheat flour with flour from sorghum (Argentina, Brazil, Colombia, and Venezuela). There are food technology labs involved with the use of sorghum flour to extend wheat at the Manfredi Station in Argentina and in the labs at the Campinas Station of Sao Paulo State in Brazil.

There is also the possibility of some direct use of sorghum as a food in North-Eastern Brazil and possibly Colombia where the greater stability of sorghum over corn can be expected to result in higher, more stable yields for the poor farmer.

Clearly, ICRISAT, with its vast experience with food quality type sorghum is in a unique situation to contribute.

# TRIP REPORT

## BRAZIL, MARCH 10-23, 1978

L. R. HOUSE

(I) Introduction:

The visit to Brazil was given initial shape at the sorghum meeting in Buenos Aires. Dr. Robert Shaffert, coordinator for sorghum improvement for EMBRAPA; and, Mahmed El Faris were there. It was decided that I would first visit the National Corn and Sorghum Center in Sete Lagoas and travel to the semi-arid region in the agro-industrial area of the San Francisco River Valley in Northern Minas Gerais. Following this I would visit the EMBRAPA headquarters in Brasilia and their nearby station, Centro de Pesquisa Agropecuaria dos Cerrados, where some work is done with sorghum primarily as part of a cropping system. From Brasilia I would fly to Racife and travel in the Pernambuco State to see some of the stations and work of IPA at Serra Talhada, Araripina; pass by Caruaru, and finally visit the EMBRAPA station at Petrolina.

Sorghum Production in Brazil over the past few years is as follows

| Year | Area (1000 ha) | Production (1000 tons) |
|---|---|---|
| 1971 | 80 | 170 |
| 1972 | 120 | 220 |
| 1973 | 210 | 400 |
| 1974 | 250 | 500 |
| 1975 | 230 | 483 |
| 1976 | 210 | 553 |
| 1977 | 178 | 435 |

The level of production has shown a rather dramatic increase.

Production of sorghum by State in Brazil is as follows

| State | Month of final harvest | Area ha | Production tons | Yield kg/ha |
|---|---|---|---|---|
| Brazil | | | 435446 | |
| Ceara | August | 2000 | 1600 | 800 |
| Rio Grande do Norte | August | 4615 | 3733 | 809 |
| Pernambuco | August | 106 | 152 | 1435 |
| Minas Gerais | May | 2290 | 2748 | 1200 |
| Espirito Santo | May | 205 | 615 | 3000 |
| Sao Paulo | May | 56540 | 168620 | 3000 |
| Roraima | March | 855 | 3470 | 4058 |

Production of sorghum by State in Brazil (contd..)

| State | Month of final harvest | Area ha | Production tons | Yield kg/ha |
|---|---|---|---|---|
| Santa Catarina | April | 450 | 1320 | 2933 |
| Rio Grande do Sul | May | 91000 | 214000 | 2352 |
| Mato Grosso | May | 4583 | 8258 | 1802 |
| Goras | May | 15000 | 29625 | 1975 |
| Other | | | 305 | |

Currently, the areas sown in the three north-eastern States of Ceara, Rio Gran. de do Norte, and Pernambuco are modest; particularly, Pernambuco. The States of Sao Paulo and Rio Grande do Sul have the greatest production but this is very largely for animal feed and produced on larger mechanized farms.

(II) Reception and Interest in ICRISAT Participation in the Sorghum Improvement Program of Brazil:

From the time I arrived at Sete Lagoas until I left Petrolina I was made aware of a keen interest in having ICRISAT place a man, particularly in the North-East, to work on sorghum improvement. This was true of both technical and administrative people. Dr. Jose Gabral told me that EMBRAPA was placing emphasis on my visit and wanted something to come out of it indicating that Brazil had financial resources to support initiation of such an effort. In response to this wide scale expression of interest I organized a technical statement to be modified in Brazil and hopefully to be ready by the first week of June when Drs. Blumenschein and Swindale will meet. This statement was organized at Petrolina and was to be typed and sent to R. Shaffert, National Coordinator for sorghum, and to Mario Lira, Coordinator of sorghum and millets work in Pernambuco State. The director of the EMBRAPA station at Petrolina, Dr. Renival Alves de Souza, may also have used this statement in a visit with Dr. Blumenschein shortly after my visit. It is only a technical statement and clearly does not commit ICRISAT.

As of the 15th of May, this statement has not arrived. However, invitations were cabled for Dave Andrews and Bob Willey to visit. Dr. Renival was concerned that moving ahead on sorghum alone might in some way reduce the opportunity to have a more inclusive farming systems, pearl millet, sorghum program. Possibly, when he visited Dr. Blumenschein, following my visit, he pushed for this more inclusive approach.

The reasons for this enthusiastic response appears to stem from several interests. The need to increase cereals production in the grain deficit North-East and sorghum appears to be a promising crop for this

purpose. The sorghum program in the North-East todate has been one of screening introduced germplasm. A program momentum has been built up and there is a need for a more in depth breeding effort. No one in the North-East is free at this time to spend full time on sorghum improvement and the departure of Mohmed El Faris has been felt. Of interest to the country, probably more so than to ICRISAT, is the interest in sweet sorghum as a source of alcohol. Even there, though, there would be spin off from the ICRISAT input in terms of new introductions and source of disease and insect resistance. Dr. Renival, director of the station at Petrolina, is anxious that ICRISAT also consider stationing a man to concentrate in the area of farming systems. Dr. Mario Lira, sorghum and millets coordinator for IPA, expressed interest in ICRISAT stationing a man to concentrate on pearl millet improvement.

(III) A general reaction to Brazil:

I had the opportunity to travel some 600 kilometers from Sete Lagoas to Januaba in Minas Gerais; to travel from Recife to the North-West corner of Pernambuco State (Araripina) and then travel south to Petrolina - a distance of about 800 km; and finally from Petrolina to Salvador about 600 km in the State of Bahia. What one sees and the response to it tend to be the same, vast vast undeveloped areas, also, one is impressed by the substantial problems in the development of these areas, and the tremendous rewards that can come from their development. The Cerrado soils are acid (pH around 4.5) with problems of aluminium toxity and a serious deficiency of phosphate (for which there are not good resources in the country). In the North-East the lack of moisture presents restricting problems in vast areas. In some areas (the drier ones) proper management of natural vegetation and feed stuffs appears of paramount importance; and in others (where rainfall is better), the opportunity for land clearing and grain production appears to be worthwhile. One simply cannot but be impressed by these vast almost population free areas; but also, with the tremendous investment that must be made to really make them productive. To a degree, sorghum is still a crop to really be introduced to these areas. Research on sorghum improvement is primarily directed to an exploratory situation.

(IV) Stations:

The Centro National de Pesquisa de Milho e Sorghum (CNPMS) began in 1976. The station of 1,911 hectares is located near Sete Lagoas. The vegetative cover is of the Cerrado type. The soils are acid with aluminium toxicity and are very low in phosphate.

The complement of staff to work on corn and sorghum is extensive:

Director
Assistant Director - Technical
Assistant Director - Administrative

Stores (one)
Climatology (one)
Extension (one)
Rural Economics (one)
Entomology (two)
Statistics (one)
Soil Fertilization (Three)
Physiology (one)
Pathology (two)
Soil Conservation (one)
Mechanization (one)
Maize Breeding (four)
Sorghum Breeding (two)
Microbiology (one)
Seed Production (one)
Chemistry (one)
Germplasm (one)

Facilities of the station are good, adequate office and labs in attractive buildings. There is a farm operations area that at quick glance appeared modest for the size of the station. Rainfall averages about 1200 mm/year.

The National Corn and Sorghum Center is on the highway between Belo Horizonte and Sete Lagoas; about 10 km from Sete Lagoas. Belo Horizonte is connected to Rio de Janerio by a shuttle air service. The road from Belo Horizonte is excellent and the distance is 70 km. Belo Horizonte is a large city with expanding industrial imput - availability of goods and services would appear to be quite good. Sete Lagoas is a smaller town but certainly a comfortable place to live. There are no towns in Pernambuco State, in the semi-arid regions, as nice as Sete Lagoas as a place to live. This point was made several times by Bob Shaffert.

Bob Shaffert and I travelled from Sete Lagoas to an agro-industrial project in the San Francisco Valley. This area is along the northern border of Minas Gerais and is in a semi-arid climatic situation (750 mm average with range from 300-400 to 1200 mm). This year the rains were good so everything was green. The crops were excellent, vigorous and productive - I was impressed.

Anthracnose was a problem in the area, being severe on some fields and almost absent on others (different sowing dates). The soils are deficient in mangenese and zinc and have a very high water penetration rate.

Certainly one was impressed with the production potential of this area if moisture is adequate.

I had the opportunity to visit Brasilia, and the nearby EMBRAPA station, Centro de Pesquisa Agropecuaria dos Cerrados. Very little work

on sorghum is undertaken although Dr. Ade da Silva, wheat breeder, is including sorghum in some of his efforts to evaluate crop response to the acid Cerrado soils and as part of a cropping sequence. Most interesting for me at this station was to see the difference in varietal response of wheat to the Cerrado soils, and the tremendous difference that added lime and phosphate makes to crop development. The approach taken to simultaneously identify tolerant plant types and also determine management steps required appeared to be good. I became more convinced of the value of screening the world collection and other useful germplasm material in this situation.

While at Brasilia (about 900 to 1150 meters elevation and 1500 mm rainfall) I had the opportunity to meet and talk with Drs. José Irineu Gabral (President of EMBRAPA) and Almiro Blumenschein. Notes made following my visits with these men are included in the attachments. Both were keenly interested in collaboration with ICRISAT for sorghum improvement particularly in the North-East.

I spent a week end in Racife and find it a pleasant place to live. There is an extensive beach that was most popular on Sunday - one wondered if anyone was still at home.

On Monday morning Dr. Mario Lira and I paid a brief visit to the IPA station in Racife. IPA is the research organization for the State of Pernambuco. There are nine people concentrating their time on sorghum and millets. IPA works in association with and receives some funding from EMBRAPA. Funds are also received from several other organizations; Sudene for millets, Bank of the North-East for grain and forage sorghum, a Canadiam organization and EMBRAPA for sweet sorghum; and funds come from the State and University. However, Racife is on the coast with high rainfall and not in a region where sorghum is a crop of interest. Some 40 km inland there is a station, still not in the semi-arid area, but where some more intensive activities, such as crossing, could be undertaken. This station could also be used in the off-season; there are about 10 acres of irrigated land with the University in Racife that could also be used for off-season activity. Without doubt, Racife is the best place to live in the State and no doubt among the best in the North-East. It is about 2 hours and 40 minutes flying time to Rio and about 5-6 hours to Belo Horizonte (because of connections). It is distant from useful stations in the semi-arid areas; contact with crop is restricted unless a staff member is willing to spend much of his time away from home.

The green coastal belt is about 50 km deep with 8 months of rain and 4 months dry. Crops commonly observed are corn, beans, casava, castor, and forage. The area remains green throughout the year.

About two hours driving time (140 km) west of Racife one reaches the town of Caruaru (500 meters elevation). This is the second

largest city in the State with a population of 200,000 (a bit bigger than Sete Lagoas). Caruaru is situated in a rolling country side receiving about 700 mm rainfall annually (beginning in March-April and ending in June-August). There is an IPA station (160 hectares) nearby that has a rolling terrain. There is a river but the water is salty. Mario Lira rents land from farmers for some of the research activities of the sorghum program. Buildings on the station are limited and in poor condition. The advantages of this location are: (1) it is situated in the North-East where a priority effort is wanted; (2) it is in a semi-arid situation (but not Cerrado soil); (3) it is about 2 hours from Racife where there is an international airport; and (4) it is a reasonably large town where a family could find relatively adequate living facilities - a weekly trip to Racife would not be difficult.

Near Serra Talhada is a large IPA station (4000 hectares) about 7 hours drive from Racife. The station is gently rolling with adequate good aluvial land and water (there is a large lake). It is a sorghum station and the one where Mohammed did much of his work. Two crops a year are possible. Facilities are modest, there is some staff housing on the farm. The town is small and it would be difficult for expatriot staff to live happily there. Distance from Racife and the living conditions detract from this location as a place for resident ICRISAT staff.

The night was spent near Serra Talhada and the following morning we drove about 4 hours to Araripina in the North-West corner of the State. The size of the station is adequate, the soils light and of the Cerrado type (acid, aluminium toxicity and low phosphate); rainfall over a 13 year period has averaged 740 mm ranging from 200 mm in 1961 to 1500 mm in 1974. There are only 2 or 3 buildings on the farm small in size (one or two rooms). One is an open type shed for equipment. The town is small and not adequate for living by an expatriot family.

The three stations of Caruaru, Serra Talhada, and Araripina would be useful to a sorghum improvement program because problems of the crop at these locations differ some. If a man were to live in Racife he would be interested in land at the University and at a station some 40 km away.

From Araripina I travelled to Petrolina to visit the EMBRAPA station for the North-East - Centro de Pesquisa Agropecuaria do Tropico Semi-Arido.

The town of Petrolina is satisfactory for living, the station is good but it is in a low rainfall area - more arid than semi-arid. This is well known and has been of concern to previous ICRISAT staff looking at the station.

I talked several times to the "Chefe" of the station, Renival Alves de Souza, about location. He was concerned; one, that I was talking only about sorghum; and two, that he wanted the ICRISAT group in the North-East association with the EMBRAPA group at Petrolina. I indicated that we would be interested in having the ICRISAT man associated with EMBRAPA and while concentrating in the North-East participating in the National program and even regionally - he concurred. I also indicated that there are already some 20 EMBRAPA staff members in IPA stations so an ICRISAT man could be administratively associated with the station at Petrolina but situated, say at Caruaru where he was in a semi-arid region. He concurred that such an arrangement would be satisfactory and that with such an arrangement it would not be necessary for all ICRISAT staff to be in the same place.

(V) Comments on Research:

(a) Cerrado Region

The term "Cerrado" refers to a type of scrubby tree vegetation and underbush but is associated with acid soils (pH 5 or below), high exchangeable aluminium, and poor fertility (particularly phosphorous). These soils are red and yellow; the red soils respond faster to correction and have a somewhat better water holding capacity but they have a poorer nutrient base than the yellow soils. They acount for 25-30% of the land area of Brazil and extend from Sao Paulo in the South to the Caribbean. When a crop like sorghum or soyabeans is sown on newly cleared soils without correction the growth is extremely poor. Rice is a more tolerant crop. Variation does exist in sorghum for response to these conditions and this should be exploited - ICRISAT could contribute especially by providing a strong germplasm base.

If the pH of the soil is increased to 5.2-5.4 with lime the aluminium is tied up (not toxic) and fertilization is more effective. If the pH is raised to 6.5 it is estimated that application of lime would be required once every 4 or 5 years. Dr. De Silva has found with wheat types tolerant of these acid conditions that soil pH near the roots is raised to pH of 6.5. This was not true of susceptible varieties in the presence of aluminium - it was if there was no aluminium. Simple field screening has been found to be adequate to identify tolerance.

(b) Sorghum Development In Pernambuco State

Research for the improvement of sorghum began in 1959 but the project was shifted from man to man and there was no take off. It was not until Mohamed El Faris arrived in 1973 that a solid program began. Mohamed introduced 2500 entries of diverse origin and selected in this material. There has been some take off with forage types but not grain. A problem with grain has been the attempt to use bitter bird resistant types. Purina tried to use these and stopped. Also, these has been no price support for sorghum and no market development. They have now introduced better grain types, including yellow endosperm. However, the strongest

funding is to develop a sorghum useful for the production of alcohol.

The program to date has been one of evaluating introductions. They are not interested in incorporation of diseases, insect, drought resistant traits, grain quality, sweet stems for alcohol etc. They are moving more or less from a screening program to one of breeding where more activities are involved. The loss of Mohamed at this time is felt. It is for these reasons that they are anxious for a sorghum man from ICRISAT.

Mario Lira is coordinating the sorghum and millets projects in Pernambuco State. He spends about 1/3 of his time with the University where he teaches from 4 to 12 hours a week. The other 2/3's of his time is spent with IPA. There are 9 agronomists with IPA concentrating their time on sorghum and millets. The leaders of the sorghum and the millets projects are stationed at Serra Talhada. Training is an important aspect of their program. At the moment there is one Ph.D., there will be 4 M.Sc. when they finish school (2 are about to finish) and 5 with the B.Sc.

In the IPA network there are 3 main stations and 7 substations for testing. There is a very close working relationship between IPA and the University at Racife.

There are sorghum breeding programs in each of the 4 north-east states, Ceara, Rio Grande du Nord, Paria, and Pernambuco. Research in Ceara and Rio Grande du Nord is with the University and in Paria, with the Ministry.

In Ceara there are 3 agronomists working with sorghum, one has an M.Sc. There are two sorghum workers in Rio Grande du Nord. The men in the Universities in both States have teaching responsibilities.

Several points of interest developed in conversation with Mario Lira.

(a) That increase in corn production matches the increase in population. Now the competition for poultry feed pushes them into a deficit situation.

(b) They would like to increase the production of sorghum for poultry feed and hold their corn for food.

(c) There has been almost no increase in per hectare yield of corn - the increase has come from increased land under production.

(d) About once in 5 years the corn crop is bad. The average yield of corn is about 800 kg/ha and in bad years will drop to 400. The whole area is usually not affected in

bad years - there are bad pockets - the production over the whole area tends to equalize.

(e) About 99.9% of the corn crop is intercropped usually with beans but also with cotton.

(f) The agriculture is usually of a shifting type - new lands are brought under cultivation as old lands are exhausted.

Serena, from Serere in Uganda, has been one of the better introductions but requires improvement in grain quality. It would be good to look at the 2KX types as well as the New Good Grain Composite that was with San Mukuru. The indication is that varietal types adapted close to the equator will do well in the North-East of Brazil.

Insects are important limiting factors to production. Midge is a common, widespread problem particularly severe on late sown sorghum.

Elasmopalpus lignosellus: This insect was very bad at Araripina but is not widespread. The insect travels under the ground apparently at night. It cuts the base of seedling plants; frequently tillers will grow but these can also be cut. The problem is frequently worse in dry weather. Without treating a field at Araripina with aldrin this insect can virtually destroy the crop. It seems to prefer sorghum first, then maize, then millet; however, rather striking variation was observed in level of attack in one nursery at Araripina. Possibly, useful progress could be made by breeding.

Drought resistance also is an important priority for any breeding effort.

I feel that it would be useful to make preparations with good food quality sorghums that are normally made for maize. If satisfactory food products are possible the farmers might realize better and more stable yields from sorghum.

## VISIT WITH DR. ALMIRO BLUMENSCHEIN

Dr. Blumenschein asked me about the trip and my reaction to the sorghum work going on at Sete Lagoas. After responding, to this I outlined to him the current position of ICRISAT at CIMMYT and the tenure of the program under IDRC funds. I also indicated the interest of ICRISAT to cooperate with Title 12 when it gets off of the ground but that we were looking at sorghum in the America's not ruling out the possibility of stationing people to create a regional center.

Dr. Blumenschein indicated that in Brazil they were interested in establishing links with Institutes but not in hosting one. He indicated that they now have links including staff stationed in Brazil with CIAT, CIP and IITA and that they have strong cooperation with CIMMYT but with no personnel. He expressed a strong desire for cooperation with ICRISAT and would welcome ICRISAT presence. He indicated that EMBRAPA could even provide funds (possibly from a World Bank Loan) to help initiate cooperative activity. He also indicated that ICRISAT staff stationed in Brazil could have courtesy employment by the Inter American Institute for Agricultural Sciences (IICA). An individual carrying the identity of this organization can travel freely in the America's.

At the time that I visited Dr. Blumenschein I had not yet been into the North-East. I indicated to him my impression of the Cerrado area and the potential I could see in sorghum and other crops. I indicated that the sorghum germplasm thus far looked at on the Cerrado was almost entirely of US origin and felt that it would be worthwhile looking at the world collection and good agronomic types of African and Indian origin. We talked about the array of sorghum problems in Brazil and how ICRISAT, if they would station someone in Brazil, should usefully have the opportunity of the sorghum research organization of the country. I indicated that Bob Shaffert (sorghum coordinator for EMBRAPA) suggested that the man be stationed at Sete Lagoas where there is a community of sorghum scientists and work regionally within and outside of Brazil from this base. Dr. Blumenschein could see no difficulty if a program would develop along that line.

Finally, I indicated that Bob Shaffert and I had talked of my organizing a statement after I had visited the North-East and send copies to him and Mario Lira, head of the sorghum program for Pernambuco State. The three of us would try and finalize a statement that we could present to our respective administrators. Dr. Blumenschein said that he would be seeing Dr. Swindale in early June so I indicated that I would try and have this statement finished by then.

In closing Dr. Blumenschein again indicated the interest that EMBRAPA has in cooperating with ICRISAT.

## VISIT WITH JOSE IRINEU CABRAL, PRESIDENT OF EMBRAPA

After talking with Dr. Blumenschein I was asked to visit with the President.

Mr. Cabral, like Dr. Blumenschein expressed a strong desire for cooperation with ICRISAT however, he placed strong emphasis on the North-East and did not waiver from the position very much. In covering essentially the same ground with him as with Dr. Blumenschein he did not balk at centering a man at the National Corn and Sorghum Center at Sete Lagoas but he kept coming back to the North-East.

Mr. Cabral was almost more direct than Dr. Blumenschein indicating the availability of funds from Brazil to initiate cooperation with ICRISAT. He talked some about problems that they have had getting started with sorghum in Brazil but he felt strongly that it had a place and was prepared to recommend pricing policies that would be encouraging when appropriate. He told me that they were anxious about my visit and very much hoped that something would materialize from it. I indicate that I was impressed with the enthusiasm for cooperation with ICRISAT that I had encountered since entering Brazil. I mentioned that I was particularly happy to find the same desire among sorghum people at Sete Lagoas who might eventually be working colleagues of anyone that ICRISAT might finally station in Brazil.

Finally, he was concerned that some positive steps be taken to get EMBRAPA and ICRISAT together. He indicated that he was not technically qualified; at this point I mentioned the plan to have a proposal jointly organized by Mario Lira, Bob Shaffert, and myself indicating that we would try and have this finished by the time that Dr. Blumenschein would see Dr. Swindale in early June. He was happy to know about this feeling the approach to be good and indicating that it was just such a paper that brought CIAT and EMBRAPA together. He requested a copy of the paper.

## SUGGESTIONS RELATED TO THE STATIONING OF AN ICRISAT MAN IN BRAZIL TO WORK ON SORGHUM

This statement was made in Petrolina in response to questions from the "Chefe" of the station, but was also to be sent to Drs. R. Shaffert and Mario Lira.

I have had the opportunity to visit the National Corn and Sorghum Center at Sete Lagoas, the National Center at Brasilia, look at the sorghum work of IPA in Pernambuco State, and to visit the EMBRAPA center at Petrolina. Universally, I was greeted with a strong desire for ICRISAT to station a man to concentrate on sorghum improvement particularly in the North-East. This statement represents my ideas as to how and where this might be undertaken - it carries no approval from ICRISAT. Hopefully, this statement will facilitate organization of a proposal including comments from staff at the Petrolina station, Mario Lira (IPA) and Bob Shaffert, sorghum coordinator for EMBRAPA.

The reason for the enthusiastic response for ICRISAT to place a sorghum man in Brazil appears to stem from a determined interest to expand cereal production particularly in the North-East and also on Cerrado soils; and, to maintain and expand the sorghum improvement program begun in the North-East. At this time, there is no one who can concentrate full attention on sorghum and the need for a strong technical imput has been felt particularly since the departuere of Mahamed El Faris.

The thrust of the problem appears to be two fold. Improvement in the production of grain andforage by intensive cultivation on large mechanized farms to help reduce the constant cereals deficit situation of the North-East; and, to develop food type sorghums useful as an intercrop by subsistance level farmers.

If an ICRISAT man is stationed in the North-East it is suggested that he have a regional responsibility within and outside of the country. More locally, it has been repeatedly expressed that he should coordinate sorghum research in the four states of the North-East and possibly where relevant in adjacent states.

It is recognized that an agreement would be made between EMBRAPA and ICRISAT and that the ICRISAT man would work within EMBRAPA, associated with the station at Petrolina but positioned at the IPA station at Caruaru (or possibly at another location if this should prove better). It is recommended that the ICRISAT man be recognized by the Inter American Institute for Agricultural Science so that he can travel easily within the Americas.

In rough outline it is suggested that the responsibilities of the ICRISAT scientist would be:

(1) In cooperation with the National Center for Corn and Sorghum at Sete Lagoas assist with good cooperation between sorghum programs in the states of the North-East.

(2) As and when desirable place entries in National trials.

(3) Participate in planning programs related to sorghum improvement at the National level and in the states of the North-East.

(4) To make at least an annual visit to sorghum programs in other countries of the region to facilitate rapid interchange of ideas and materials.

(5) To help identify individuals throughout the region for training at ICRISAT and to do a reasonable amount of in-service training within Brazil.

(6) To introduce the world sorghum collection and other potentially useful materials from other parts of the world and evaluate as appropriate for

(a) Ability to produce satisfactorily under conditions of low pH, aluminium toxicity and low phosphate availability. Variability in response to these traits is known to exist.

(b) Evaluate for resistance to the following insects:

i. The stem borer - Diatraea saccaralis
ii. Elsmopalpus lignosellus
iii. Spodoptera frugiperda
iv. Midge

(c) Evaluate for resistance to anthracnose.

(d) Evaluate for drought resistance.

(e) Bird control.

(f) Evaluate sorghum for food quality using local preparations primarily for maize.

(g) To develop sorghums useful for intercropping.

(h) To select useful forage types.

(i) To provide potentially useful types for alcohol production to the National center at Sete Lagoas.

It is important to appreciate that screening for these traits should be done at several locations where conditions are optimal; for example, low pH, aluminium toxicity and low phosphate at Sete Lagoas or Araripina; resistance to Elasmopalpus lignosellus at Araripina, anthracnose resistance at Caruaru, and midge resistance at Serra Talhada.

(7) Suitable programs of breeding and crop improvement would be expanded or initiated following preliminary screening as considered useful.

(8) Caruaru has been suggested as a location to center the sorghum work recognized some limitations.

(a) It is in the semi-arid tropics with a rainfall pattern similar to areas where sorghum can be intensively produced.

(b) It is the second largest city in Pernambuco State so offers reasonable living conditions.

(c) It is two hours by road to Recife for family interests and particularly to facilitate business travel.

(d) Many of the problems of the crop are expressed there so effective selection is possible.

Disadvantages are:

(a) Rolling terrain of the station possibly requiring use of land off station or acquiring more land.

(b) Only limited water available for irrigation to support off-season crop activities.

(9) Interest was expressed in having ICRISAT place a man, preferably in the North-East, to concentrate on the improvement of pearl millet and to work in farming systems.

TRIP REPORT

MEXICO, CIMMYT - March 24-27, 1978

Vartan is fitting in well at CIMMYT apparently working effectively with the CIMMYT staff. He finds CIMMYT a very efficient institute which he much appreciates.

He also had his report finished for his visits to Guatemala, El Salvador, Nicaragua, and Colombia. To help broaden our information about sorghum in the Americas he also organized a statement about Mexico. The information that he had and comments gained are worthwhile. His approach was good, and the information that he gathered useful. A copy of his paper is included (APPENDIX 1).

We talked about the program for the development of early cold tolerant types suitable for the high elevations of Mexico. Two points were emphasized. The ICRISAT program would concentrate on white seeded types of food quality. Both the programs at INTA and Chapingo have coloured types so there is no need to duplicate. Second, an effort will be made to relate days to flowering with elevations at which the different materials maybe useful. It maybe sometime before sorghums are available for the rainfed tracts at 2200-2300 meters elevation; however, useful materials at elevations between 1500 and 2000 meters maybe available and could be directed toward farmer use.

We feel that selective operations should be undertaken at El-Batan for agronomic traits in the cold environment and at Poza Rica, in the summer, for disease reaction. The winter nursery would be used for non-selective activities. The purpose is ti get away from making selections for anything but non-variant characters in the winter at Poza Rica - a season very different from El-Batan in the summer.

It appears best, in diversifying the genetic base in the program to concentrate, initially at least, on the early good grain quality types from Hyderabad. These will be crossed to good grain types that are cold tolerant and early. Hopefully, it will be possible to realize earlier good qrain cold tolerant types in segretating generations.

The genetic base needs to be expanded but crossing to accessions from the high elevation areas of East Africa results in progeny that flower in 120-140 days days at El-Batan. It is worthwhile to introduce such material and select toward earliness; but, the priority is considered to be lower than concentrating on crosses with very early, good grain types from Hyderabad.

Vartan was able to obtain seed of a number of A and B lines while on his trip. He now has about 240 A and B line pairs which must be one of the largest collects existing. He will increase the seed for

distribution and run an A-line test cross using only A-lines with pearly white grain.

It was suggested, that for now, projects involving high lysine, midge, and stem borer problems be withheld until elite types for farmer use at the high elevations are available and then direct breeding objectives at solving problems in their production.

There had been some rains at Poza Rica and some plants were showing damage from disease. Vartan will score for resistance and agronomic eliteness taking maturity into account. There is a lot of phenotypically similar material that should be weeded out of the program to provide a chance for new material to come in from crosses.

The general stature of the plants in the cold tolerance program appear to be weak at Poza Rica. A plan was made to evaluate these against some of the hybrids currently in use in the lower elevations of Mexico. This will give us some information on plant type if we begin to work at lower elevations in the Americas.

Vartan also plans to bring some of the better varieties and hybrids from Colombia and look at them at Poza Rica and Tlatizipan. It is a general experience in the maize program and our experience with sorghum in East Africa that materials developed close to the equator do not move to higher latitudes. This project then, will also form part of an effort to learn more about the breeding of sorghum in the America.

Vartan plans to visit Texas A&M about April 10. About mid-June he is thinking about visiting Honduras, Bolivia, and Peru. This will pretty well round out our effort to evaluate sorghum in the Americas.

APPENDIX I

# TRIP REPORT

Guatemala, El Salvador, Nicaragua,
Colombia, Argentina, Mexico

February 5 to March 12, 1978

Vartan Guiragossian, Sorghum Breeder
ICRISAT/CIMMYT

You are probably aware that ICRISAT with headquarters at Hyderabad, India, assumed responsibility and leadership of the cold tolerant sorghum program centered at CIMMYT, Mexico from January 1977. Dr. Vartan Guiragossian who was appointed by ICRISAT in early October 1977, was asked to carry on the program.

The purpose for the visit to Guatemala, El Salvador, Nicaragua, Colombia and Argentina sorghum growing areas was to become familiar with the existing problems and particularly as it applies to the small farm situation, and also to become acquainted with the scientists in the region working on sorghum improvement.

ICRISAT's objective in this project throughout the Central and South American sorghum growing areas is to extend adaptation to highlands of the tropics, semi-arid tropical and even temperate zones in the developing world in order to intensify land usage, and also to assist in developing tropically adapted varieties and hybrids for the tropical low lands.

## INTRODUCTION

### Origin of World Grain Sorghum Production

According to Martin (1970) cultivated sorghum probably originated in east central Africa, in or near Ethiopia or Sudan. The same is stated by Doggett (1970) who also indicated that the sorghum crop today can grow in the belt between sea level and 2700 m. This could be explained by the wide variety of ecological habitats in close proximity and altitudes ranging from sea level to over 3500 m that occurs in Ethiopia.

The tropical origin of sorghum has been pointed out as a reason for the better adaptation of this crop to semi-arid and warm subhumid areas in Asia and Africa (Eberhart, 1970), where sorghum has been grown as a major cereal crop throughout centuries and it is mostly used for human consumption (Miller, 1968). The great importance of Asia and Africa as sorghum producers in the world is shown in Table 1.

Grain sorghum is relatively a new crop in the Americas. Doggett (1970) mentioned that the main grain sorghum introductions to America occurred between 1874-1908. Since then, this crop has become increasingly

Table 1. Grain sorghum production in the world in 1974 compared with 1961-65 (FAO, 1975).

| Geographic area | Harvested area (1000 ha) | | Yield (kg/ha) | | Production (1000 MT) | |
|---|---|---|---|---|---|---|
| | 1961-65 | 1974 | 1961-65 | 1974 | 1961-65 | 1974 |
| Africa | 11,518 | 12,945 | 780 | 718 | 8,988 | 9,290 |
| North and Central America | 5,368 | 7,104 | 2,723 | 2,672 | 14,618 | 18,980 |
| Asia | 20,266 | 18,723 | 512 | 516 | 10,372 | 9,666 |
| Europe | 47 | 117 | 2,249 | 3,985 | 106 | 467 |
| Oceania | 154 | 573 | 1,482 | 1,950 | 229 | 1,117 |
| USSR* | 79 | 90 | 845 | 1,111 | 66 | 100 |
| South America | 880 | 2,972 | 1,591 | 2,452 | 1,401 | 7,288 |
| World | 38,313 | 42,454 | 934 | 1,103 | 35,779 | 46,908 |

* Estimate for USSR, not included in Europe or Asia.

Table 2. Grain sorghum production in selected American countries in 1974 compared with 1961-65 (FAO, 1975).

| Country | Harvested area (1000 ha) | | Yield (kg/ha) | | Production (1000 MT) | |
|---|---|---|---|---|---|---|
| | 1961-65 | 1974 | 1961-65 | 1974 | 1961-65 | 1974 |
| USA | 4,909 | 5,632 | 2,834 | 2,833 | 13,912 | 15,954 |
| Mexico | 205 | 1,170 | 2,211 | 2,308 | 452 | 2,700 |
| Argentina | 856 | 2,500 | 1,588 | 2,240 | 1,359 | 6,100 |
| Brazil | - | 238 | - | 2,941 | - | 700 |

important, and by now it is the second ranking feed grain in the United States of America (U.S.A.). In Latin America sorghum has had an explosive acreage increase in the last 25 years as shown in Table 2. By 1975, sorghum became the third most important grain crop in Mexico (Livera, 1975) and in Argentina (Parodi et al, 1975). Tropical Latin America, like other developing regions of the world, is struggling against the crushing, interrelated problems of poverty, hunger, malnutrition and inflation, problems that have been complicated by unprecedented urban expansion as a result of rapid demographic growth and migration to the cities from rural areas. Increased agricultural productivity is an essential component in the alleviation of these problems. Those who remain in the rural areas must produce more, not only to improve the standard of living of their own families but also to feed the growing percentage of people engaged in non-agricultural activities.

The combination of rapidly rising population and increased purchasing power is expected to result in an annual increase of 3 to 4 percent in demand for food during the next ten years. Unless food production rises at an equally rapid pace, growing in inflationary pressures on food products can be expected. This can only create additional hardships on the lower income segments of the population who spend most of their income on food and who need to improve first the quantity and quality of their food consumption in order to overcome serious malnutrition.

Grain sorghum is becoming increasingly important in Latin American countries from both an economic and nutritional point of view. One only needs to look at agricultural statistics for Latin America to see the rapidly expanding sorghum areas. (Table 3).

The increase in area sown to sorghum has been dramatic in Guatemala, Mexico, Argentina, Brazil, Colombia, Uruguay and Venezuela. Although the total area sown is small, the increase in area in Costa Rica and Dominican Republic is great. The area sown to sorghum has increased in El Salvador and has been relatively constant in Nicaragua. Argentina and Mexico, two pre-hybrid sorghum producing countries which now have more than half their area in hybrids, have increased hectares in sorghum by more than 30 and 12 times, respectively since the pre-hybrid years of 1948-52[1]. On the contrary, El Salvador and Guatemala with less than 20% of their sorghum in hybrids and using domestic or native varieties have increased land in sorghum by only 1 1/4 and 3 times respectively.

In addition to likely increases in these major producing countries there remain several potentially favourable producing areas in Latin America. Of this group Brazil with one of the few undeveloped areas of the world, the

1 Estimate of 100,000 ha. for Mexico in 1948-52 - FAO statistics.

Table 3. Area sown to sorghum (ha x 1000); average per hectare yields (kg/ha); and production (1000 metric tons) for several Central and South American countries (FAO Production Year Book 1974).

| Country | Area 1000/ha | | | | Yield kg/ha | | | | Production 1000 MT | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1961-65 | 1972 | 1973 | 1974 | 1961-65 | 1972 | 1973 | 1974 | 1961-65 | 1972 | 1973 | 1974 |
| Costa Rica | 5 | 8 | 4 | 9 | 1610 | 1686 | 2000 | 1798 | 8 | 13 | 8 | 16 |
| Cuba | 19 | 13 | 13 | 13 | 1167 | 1154 | 1154 | 1154 | 22 | 15 | 15 | 15 |
| Dominican Rep. | 1 | 4 | 3 | 5 | 3716 | 3571 | 3172 | 3280 | 4 | 15 | 5 | 17 |
| El Salvador | 97 | 130 | 119 | 110 | 943 | 1119 | 1316 | 1192 | 91 | 146 | 156 | 131 |
| Guatemala | 38 | 73 | 74 | 75 | 665 | 616 | 614 | 560 | 25 | 45 | 45 | 42 |
| Honduras | 42 | 25 | 30 | 30 | 1230 | 1379 | 1400 | 1313 | 51 | 40 | 42 | 39 |
| Mexico | 205 | 1063 | 1076 | 1170 | 2211 | 2296 | 2298 | 1208 | 452 | 2441 | 2473 | 2700 |
| Nicaragua | 50 | 36 | 55 | 55 | 938 | 1061 | 1053 | 1072 | 47 | 50 | 55 | 60 |
| Neth Antille | 3 | 4 | 4 | 4 | 1667 | 1500 | 1476 | 1455 | 5 | 66 | 6 | 6 |
| Argentina | 856 | 1564 | 2282 | 2500 | 1588 | 1600 | 2261 | 2440 | 1359 | 2502 | 5159 | 6100 |
| Brazil | | | 147 | 238 | | | 1699 | 2941 | | | 250 | 700 |
| Colombia | 13 | 95 | 168 | 98 | 2378 | 2505 | 2369 | 2398 | 31 | 238 | 398 | 235 |
| Uruguay | 6 | 42 | 113 | 100 | 548 | 1348 | 1995 | 1924 | 4 | 57 | 225 | 193 |
| Venezuela | 1 | 5 | 6 | 28 | 2166 | 1415 | 1834 | 1552 | 1 | 7 | 10 | 43 |

Amazon Basin, plus other regions even more readily available for the cultivation of sorghum, offers the greatest possibility for a significant increase. Most of these potential producers will, however, require a much greater research effort to locate adapted hybrids or varieties as well as to determine suitable cultural and marketing practices.

The Central American countries are generally rugged with a central mountain chain dropping to low often fertile plains and valleys toward the East and West Coasts. Rainfall varies immensely from over 5000 to 500 mm. Generally, but not always, the higher rainfall is in the higher elevation areas. The Atlantic coast generally gets more rain and the land areas are largely in trees for timber and some plantation crops. Corn is a main staple and generally grows more on the Pacific side of these countries.

It would seem that sorghums adapted to higher rainfall tropical conditions would be generally desired; however, there are more temperate lower rainfall situation because of higher elevation situation. Environmentally, these countries are complex, highly variable. Generally, the lower areas are hot, humid with relatively high rainfall. To my opinion the greatest interest in sorghum is in the low land tropical areas of the tropical South American countries and in Central America.

It is clear that sorghum is rapidly expanding in use in these countries and that they are attempting to strengthen their input in improving the crop. An effort is also being made by several of the countries of the region to coordinate the improvement of several of their important crops including sorghum. This cooperation, in Central America, may evolve through the PCCMCA.

Most of the statistical data for this discussion was obtained personally during my visits to the Latin American countries and from the U. S. Foreign Agricultural Service.

GUATEMALA - February 5-11:

Research in Guatemala is undertaken in the organization "Instituto de Ciencia y Tecnologia Agricolas" (ICTA. ICTA developed from a reorganization of the agricultural sector, the movement beginning in 1970. There were two principal goals: increase food production, e pecially of the basic grains (which includes sorghum), and to stimulate rural development. The responsibilities of ICTA can be interpreted as follows: ICTA has a direct responsibility for creating, identifying, generating technology, testing it under conditions where it will be used, and adapting it to those same conditions. ICTA has further decided that it must know the results of the technology when in the hands of farmers.

Within ICTA, Dr. Robert Waugh is the director (Rockefeller staff) and Dr. Albert N. Plant is coordinator for the sorghum program (AID staff). Albert made my visit in Guatemala very fruitful and strongly favoured ICRISAT's cooperation in the near future in Guatemala.

Actual situation of grain sorghum in Guatemala.

Grain sorghum acreage has experienced a constant gain since 1963. Acereage increased from 40,000 manzanas to a present acreage of approximately 92,000 manzanas (1 manzana = 0.7 ha). Over the same period, yields have experienced a considerable gain. National production has increased six fold over this same period from 335,000 quintals to over 2,050,000 quintals (1 ton = 22 qq).

Surface Area, National Production, and Yield of Grain Sorghum in Guatemala

| Year | Surface Area Hectare | National Production Tons | Yield Tons/Hectare |
|---|---|---|---|
| 1963-64 | 28,000 | 15,200 | 0.54 |
| -65 | 33,460 | 26,500 | 0.79 |
| -66 | 34,230 | 42,500 | 1.24 |
| -67 | 35,560 | 33,300 | 0.93 |
| -68 | 35,140 | 31,900 | 0.90 |
| -69 | 36,750 | 34,600 | 0.94 |
| -70 | 51,380 | 44,500 | 0.87 |
| -71 | 40,460 | 28,900 | 0.72 |
| -72 | 50,190 | 36,900 | 0.73 |
| -73 | 39,550 | 37,900 | 0.96 |
| -74 | --- | --- | -- |
| -75 | 74,410 | 61,600 | 0.83 |
| -76 | 55,230 | 96,100 | 1.73 |
| -77 | 61,110 | 93,000 | 1.52 |

The bulk of this acreage is located in areas where the climate is less favourable for corn. In these areas, the yield of grain sorghum is usually 20-25 percent superior to corn even though the corn is planted in a more favourable growing period.

Production in these drier areas is concentrated on small farm units and in excess of eighty percent is seeded in association with either corn or beans. Of this production, about 64 percent is for home consumption on the farm. Forty to fifty percent is destined for human consumption directly as tortillas. Surplus from the small farm units and production from the commercial farms in the Pacific coastal plain is destined to the

seed concentrates industry. Even a two fold increase in acreage and a six fold increase in production was not sufficient to supply the demand and in 1977 the seed concentrates industry imported 4500 tons (Data from INDECA) of sorghum grain. This was caused by reduced corn yield due to drought; however, it does illustrate that it is difficult to evaluate the importance of grain sorghum without considering its replacement value for corn.

Based on my survey in Guatemala, the following answers were obtained from Dr. Albert N. Plant and Dr. Robert Waugh.

Q. Is sorghum grown in your country or region?

A. Yes.

Q. Could sorghum be grown in some part of the country which is presently not cultivated or replaces other crops? Name possible regions.

A. On highland above 1800 meters.
On lower elevations where moisture is limiting for corn.

Q. Name the region where sorghum is grown and at what elevation.

| A. | | |
|---|---|---|
| Pacific Coast | 0 - 300 meters | |
| South East (Jutiapa) | 300 - 1200 meters. | |
| North East (Zacapa) | 300 - 1200 meters | |
| Central Mountain | 300 - 1500 meters | |

Q. Present acreage cultivated with sorghum.

| A. | | |
|---|---|---|
| Pacific Coast | 0 - 300 meters | 9,500 - 10,000 ha |
| South East | 300 - 1200 meters | 38,000 - 40,000 ha |
| North East | 300 - 1200 meters | 5,000 - 5,500 ha |
| Central Mountain | 300 - 1500 meters | 9,000 - 10,000 ha. |

Q. Dates of planting.

| A. | |
|---|---|
| Pacific Coast | May and August |
| South East | June and September |
| North East | June and September |
| Central Mountain | May, September and November. |

Q. Dates of harvesting.

| A. | |
|---|---|
| Pacific Coast | August and December |
| South East | December and January |
| North East | December and January |
| Central Mountain | September and December - January |

Q. How many generations can you possibly get in one year?

A. Three genenerations commercially are feasible.
Four generations supplimented with irrigation on a ninety day seeding to planting schedule.

Q. Do farmers grow hybrids or varieties?

A. Big farmers grow hybrids.
Small farmers grow varieties.

Q. If hybrids - who produces them?

A. U.S. seed companies.

Q. Av. range of maturity days of hybrids, and Av. yield.

A. 90 - 100 days to maturity.
2600 kg/ha.

Q. What is the seed colour?

A. Red or Bronze.

Q. Who buys them?

A. Feed Mills.

Q. Grown for food or feed?

A. Feed.

Q. Any major problems with hybrids.

A. Marketing, anthracnose, weathering and maturity.

Q. If variety - who produces them?

A. Local varieties that have been present for many years.

Q. What is the breeding technique used to extract varieties?

A. Introduction from Texas - pedigree method.

Q. Av. maturity days for local varieties, and Av. yield.

A. Variable, bloom in mid-November regardless of when seeded.
Av. yield 900 - 1000 kg/ha.

Q. What is the seed colour? With or without testa?

A. White, without testa.

Q. Grown for food or feed?

A. For food mainly and the extra for feed.

Q. What are the major problems with the existing varieties?

A. Photoperiod sensitive.
Grain to forage ratio 1 - 3 therefore, low yield.
Bacterial strip.
Low protein quality.

Q. Specific regions where hybrids and varieties are grown.

A.

| | |
|---|---|
| Pacific Coast | 50% hybrid and 50% variety |
| South East | 10% hybrid and 90% variety |
| North East | 50% hybrid and 50% variety |
| Central Mountain | 25% hybrid and 75% variety. |

Q. Any insect problem, including bird damage?

A.

| Scientific name | Common name |
|---|---|
| Contarinia sorghicola | Midge |
| Diatrea lincolata | Sugarcane stock borer |
| Laphigma frugiperda | cogollero or fall army worm. |

Q. How are you handling the problem?

A. Date of planting to go around the midge, cultural practices, resistance or tolerant genotypes.

Difficult to control although insecticides are used.
Chemical control when necesssry.

Q. What stage and kind of damage done to the plant?

A. During bloom - grain fails to develop.
Any stage - destruction of the vascular tissues.
Any state - leaf damage, growing tip.

Q. Any disease problem?

A.

| Scientific name | Common name |
|---|---|
| Colletotrichum graminicola | Anthracnose |
| Cercospora sorghi | Grey leaf spot |
| Glococercospora sorghi | Zonate leaf spot |
| Pseudomonas andropogoni | Bacterial leaf strip |
| Head blight | seed mould. |

Q. How are you handling the problem?

A. Incorporate resistances into the adapted varieties and hybrids.

Q. What stage and kind of damage done to the plant?

A. Mainly leaf and peduncle.
Before flowering - leaf destruction.
Before flowering - leaf destruction.
Before flowering - leaf destruction.

Q. Is sorghum a staple food crop in your region?

A. Yes.

Q. In which form/s sorghum grain is consumed in your region?

A. Tortilla, usually mixed 50 - 50 with corn, however, in shortage of corn, use 100% sorghum.
In pop sorghum, some flour for special occasions.

Q. What is the detailed procedure to prepare the local food/s?

A. Tortilla preparation:

Place in a container 12.7 kg whole sorghum grain. Then add 58 gm cal (CaO) white powder and add enough water to cover the seeds. Place the container on a fire for 30 minutes and then let it cool for 15 minutes. Remove seed coat by rubbing against your hands and collect the seed coat. Grind seed while wet to make a dough (masa). Then make tortillas with 5 cm diameter and ½ cm thickness. Place on hot plate for about 5 minutes to cook.

Q. Which cultivar/s of your region is known to make the best food/s?

A. Cacho de chivo.
Paquete.
CENTA S-1.

Q. What are the physical or aparent characters of the grain that enable the cultivar/s named in making the particular food/s?

A. White seed coat, absence of tannin, vitreous endosperm, absence of mould and pleasant flavour.

Q. How is sorghum grain utilized in your region, apart from human consumption? Please write specific grain quality requirements of any.

A. Animal feed, low tannin types with glumes which are removed during threshing.

Q. Latitude.

A. $14.0^{\circ}$ - $15.5^{\circ}$

Q. Soil type.

A. Sandy loams, clay loams

Q. Soil pH.

A. 6 - 7

Q. Rainfall distribution.

A. May to November not uniform with a canicula not predictable.

Q. Amount of precipitation in different regions/yr.

A.

| | |
|---|---|
| Pacific Coast | 1000 mm/yr. |
| South East | 1000 mm/yr. |
| North East | 1500 mm/yr. |
| Central Mountain | 2000 mm/yr. |

Q Day length.

A.

| | |
|---|---|
| Summer | 13 hours |
| Winter | 11 hours. |

Q. Nutrient difficiencies in the soil.

A. Nitrogen and Phosphorus.

Q. Rate and kind of fertilizers applied.

A. 16-20-0 Ammonium nitrate and triple phosphate.

Q. Irrigated or dry land.

A. Dry land.

Q. Any frost during growing season.

A. Between 0 - 1500 m elevation - no frost.
Between 1700 - 2000m - December and January Frost.

Q. Length of growing season days.

A. 180 - 190 days without irrigation between 0 - 15-0 m.
The whole year round with irrigation.

Q. Lowest temperature in the growing season.

A. $20^{o}C$ between 0 - 1500 m.
$5 - 6^{o}C$ between 1700 - 2000 m.

Q. What is the most limiting factor the farmer is facing in each location?

| | |
|---|---|
| A. Pacific Coast | Midge, grain weathering. |
| South East | Photoperiod and drought. |
| North East | Drought. |
| Central Mountain | Adapted varieties and food type. |

Q. How strong is the link among private institutions, seed companies, universities, and government research centers?

A. Fair to weak.

Q. Were you cooperating with CIMMYT's sorghum program?

A. No.

Q. Do you think Mexico could be used as a center to send breeding material to Latin America?

A. Yes.

Q. Give reasons.

A. Mexico has the latitude, climate and elevations and Poza Rica station for lowland tropical adaptations.

Q. Where do you suggest the center should move?

A. Stay in Mexico.
Move to Guatemala
Move to CIAT.
Move to CENTA.

Q. How was your program run and where did you get your breeding materials from?

A. Texas A&M, Africa, Purdue.

Q. Are you interested in cooperating with ICRISAT?

A. Yes.

Q. How ICRISAT can best relate and help make a contribution in Central and South America

A. By working on programs that have interest throughout tropics but which cannot be undertaken at the local level.

Guatemala is a country of many agroecological situations. There is a broad coastal plain, varying up to 40 miles in width along the Pacific Coast of the country. Rainfall in this region is approximately 1000 mm. The rainfall across the country decreases from the border with Mexico to the border with El Salvador. Mountains rise steeply from this coastal plain and rainfall can be very high 4000 to 5000 m. Behind the mountains the rainfall drops, usually between 1000 and 2000 mm. but falls as low as 500 mm. The north western part of the country is considerably less mountainous, more sparsely populated and not in an area where sorghum is of concern. Soils are generally acid with pH of 6; some soils in very high rainfall areas are more acidic. The soil has adequate potassium but requires nitrogen and phosphate.

The major sorghum production takes place on large farms along the Pacific Coast and in the mountainous areas of Jutiapa, a provincial area in the Eastern part of the country bordering El Salvador. Possibly expansion to the West Chimaltenango (1800) and to the north El Oasis provincial areas is a possibility. The ICTSAN cold tolerant nursery planted at Chimaltenango to the surprise of the farmers produced seed and arose excitement and incentive to further improve the grain quality to make tortillas for the small farmers. Selections were made from the segregating ICTSAN material by Dr. N. Plant and Vartan, and immediately the selections were planted on the coast at Cuyuta to gain one generation before June. There is a need for earliness for these materials which Vartan is giving priority in Mexico in his breeding nursery.

The sorghum produced on the coastal plain comes primarily from commercial hybrid seed companies, Dekalb, Pioneer, Northrup King and Asgrow.

The bulk of the food grain (80%) of the country is produced by the campesino or peasant on small farms in hilly mountainous areas. This is a traditional type sorghum, growing to 3 or 4 meters in height with white grain that is wet milled after soaking in alkali and made into tortillas.

About 60 percent of the sorghum produced in this way goes into human food. The hybrids from seed companies do not serve this area at all, they are unadapted in their system and of non-food type grain quality. Locally developed varieties and hybrids for such areas are in the research stage.

Rainfall in the sorghum area varies from 1000 to 2000 mm and falls from May to mid-October early November. There is a pronounced bi-modal pattern with little or no rain in August (Canicula). In spite of this high rainfall sorghum is grown because of drought conditions. The

drought conditions arise because of the high variability in rainfall pattern and because of steep slopes, poor water penetration and thin soil layers with poor water holding capacity. Much of the cropping in these regions in Central America is more or less as follows: Corn, sorghum and beans are all grown in association in May. Sorghum is sown 28 days after corn in the same row as corn or between rows of corn. Beans are frequently intersown between rows of corn. The corn grows faster than the sorghum which is held back during the first rainy period. The corn matures by late August early September and is broken over just below the ear. The sorghum has a more favourable environment and grows through the corn flowering in mid-November. Many years due to ununiform and unpredictable rainfall distribution, the corn looks poor and sorghum will be the productive crop.

The research program of Dr. Plant is directed toward the development of varieties and hybrids flowering in about 60 days. He has close contact with Texas A&M and obtains much of his material from them. His program is fairly extensive, directed toward the large mechanized production units on the coastal plain and to try to ratoon and to undertake August sowings in the more hilly areas. He is working for a good grain quality type. He has had trouble finding good A-lines for hybrid seed production but is satisfied with 7501, 7502, 7503, 7504, 7505 series of A and B lines from Fred Miller, Texas A&M. However, he concurs in the need to identify better A and B lines and feels that ICRISAT could contribute in this respect. Some of his best hybrids resulted from the following combinations.

(1) 7504A x 77CS - 1R ——→ yielded 7118 kg/ha.
(2) 7504A x (170 x 2536)R ——→ yielded 6750 kg/ha.
(3) 7504A x 2536R ——→ yielded 6734 kg/ha.
(4) 7504A x GPR-148R ——→ yielded 6306 kg/ha.
(5) 7504A x TX430R ——→ yielded 6193 kg/ha.

Varieties were developed from crosses between TX2536 x 77CS-1 ——→ yield 5-7 tons/ha. under optimum conditions.

There are a number of production restraints that are directly related to cultural problems which must be solved by ICTA. A research organization is really effective when it anticipates problems in advance and resolves them before they become a problem for the farmer. The appearance of downy mildew (Sclorospora sorghi) in Guatemala presents a test case for the efficiency of the sorghum program of ICTA.

Except for a few large commercial farms the production of sorghum grain has been limited to the second growing season (August to January) so that the grain can be harvested during the dry period. Even the large commercial farmer experiences market discount problems with May planting due to grain deterioration before harvest.

On traditional farms, the use of approved practices is limited. The tall late varieties mature under moisture stress and the farmer is reluctant to fertilize or adapt practices which increase investment.

The major production restraints for each region of Guatemala where sorghum is grown for grain is presented below.

Region IV

The major factor limiting the production of sorghum grain is the sorghum midge (Contarinia sorghicola). The area between Escuintla and the frontier with Mexico is highly infested. Sorghum will be an excellent alternative crop for the second growing season provided that the midge problem is resolved. At present, it is impossible for the medium or small farm unit to cultivate sorghum. Field deterioration is a major problem for May or June seedings.

Region V.

Lack of adaptable short season, food type varieties with high yield potential has limited acreage and the varieties currently being grown produce extremely low yields in this region.

A second constraint is uneven distribution of rainfall. Introduced varieties must be not only be of short season, but also drought resistant.

Region IV:

The main factor limiting production of grain sorghum is the cultural system employed. More than eighty percent of the sorghum is planted in association with either corn or beans and matures during the second growing season when the rains have ceased.

In the coastal plain, the late maturing varieties are subject to heavy midge damage. Rainfall distribution is very uneven, varying from a complete lack of rainfall to excessive rainfall which permits field deterioration of the grain before harvest.

Region VII:

The production restraints in this region are the same as Region V.

Objectives of the Sorghum Program of ICTA:

The desire of the sorghum program of ICTA is to increase the unit area production of sorghum grain, and the national production of

sorghum, and to increase the level of living for the medium and small farm unit. The objective of the grain sorghum program of ICTA can be outlined as follows:

(1) To develop non-photoperiod sensitive, tropically adapted, high yielding, food type grain sorghum varieties; hybrids for the drier areas and for use by the upland farmers who do not plant in association with corn or beans. Dr. Plant feels that ICRISAT could contribute in this respect.

(2) To develop photoperiod sensitive varieties that will bloom under conditions of slightly longer days and thus bloom in the farmer's fields around the middle of October rather than in November as is presently the case.

It seems that a contribution could be made if some 30 to 45 days were removed in the time to flower. With rains stopping in mid-October to November moisture frequently becomes limiting on these droughty soils and yield is reduced. Also, the grain straw ratio is about 1 to 5 indicating that there is a lot of dry matter production but mostly in leaves and stems. A change in plant type would likely result in higher yields. Less work has been done to develop suitable types for the long growing season. Dr. Plant feels that ICRISAT with its opportunities in Africa and Mexico should be able to help develop such material.

(3) To develop midge (Contarania sorghicola) resistant varieties and hybrids which possess desirable agronomic characteristics and yield potential.

The major insect pest is the midge. This insect entered Guatemala a few years ago from Mexico and has just about entered the sorghum area adjacent to the El Salvador border. Breeding for resistance to this insect is an important part of the ICTA program. Therefore sources of resistance from Texas A&M and ICRISAT will be useful. Dr. Plant using the Texas sources for midge resistance, recovered only about 10% infestation in fields where normals were 40-60% infested.

In midge control, the goal is to reduce the flowering period to a minimum, plant fields against prevailing wind direction and seed early so that flowering occurs before the seasonal build up in the midge population. Most insecticides (Diazon, lannate) are effective in killing the midge adults present in the field; however, the source of the infestation should be determined. If the insects are airborne from the other fields, control will be more difficult. One midge per head is sufficient to warrant an insecticide application.

The other main insects attacking grain sorghum are: The Fall Army Warm (Spodoptera frugiperda) and the sugarcane borer (Diatraea saccharalis). ICTA seeks ICRISAT's help in finding sources of resistances to these insects too. At this stage the first line of defence against insects is a good management program that maintain all fields in an actively growing state. The second line of defence is the judicious use of insecticides. There are many insecticides available that are excellent for controlling these insects before they enter the stalk. However, one should be extremely cautious using parathion on grain sorghum because of its toxic effects on some varieties and hybrids. With any insecticide, the best practice is to spray when the insects are small and will be killed by minimal insecticidal application.

(4) To incorporate disease resistance, especially downy mildew (Sclerospora sorghi) resistance, and anthracnose (Colletotrichum graminicola). Also grey leaf spot (Cercospora sorghi) and zonate leaf spot (Gleocercospora sorghi) are foliage diseases found in the more humid regions; however, they cause much less damage than anthracnose.

Anthracnose (Colletotrichum graminicola) is the most common and serious disease of grain sorghum in Latin America, especially in Brazil, Venezuela and Guatemala. This disease can attack the foliage, the stalk and the panicle. Anthracnose in the head was mentioned as the number one yield limiting factor. Anthracnose on the leaves and stem apparently is much less severe. Sources of resistances in varieties and hybrids are available with Texas A&M. Varietal reaction to anthracnose in Guatemala appears to be similar to that in the U.S.A., however, reactions in Venezuela and Brazil are reported to differ. This racial difference, if real, would be important to a crop improvement program. Resistance to anthracnose could be undertaken as part of a research program of an ICRISAT Center in the America's.

Downy mildew (Sclerospora sorghi) of corn and grain sorghum is appearing in Latin America but, it is not yet serious in Guatemala. Few resistant varieties of grain sorghum are available. Downy mildew has entered Guatemala from Mexico and is slowly moving in the country. It is also present in El Salvador and Honduras. At present the severity is low and the disease is almost not found in the coastal areas. There is fear of its spread and it was felt that in the not too distant future quarantine may require that seeds that move internationally in the region come from fields certified to be free of this disease. There is a greater fear of downy mildew on corn because it can be more devastating and more difficult to realize resistance through breeding.

(5) To incorporate resistance to field deterioration of the grain into all varieties and hybrids with special emphasis on the food

type grains for tortillas. ICRISAT, with its opportunities in Africa and India should be able to help develop such materials.

(6) To increase the nutritional and food quality of the sorghum grain with special emphasis on digestibility, protein content and quality, and palatability and appearance. Sources of material for this purpose will be obtained from Texas A&M Purdue and ICRISAT.

(7) There are other possibilities in the cropping sequence, such as sow sorghum in May, harvest in August during the dry period and ratoon harvesting again in November. Other possibility, where corn might be sown in May, and harvested in August and sorghum sown in August to be harvested in November. However, because the rainfall in August is very uncertain, sowing in August will be risky. The general opinion in all Central American countries is that small farmers in elevations ranging from 800 to 1200 meters will likely not be able to move away from combined sowing of corn and sorghum in May.

(8) There is a regional yield testing program in Central America for several crops including sorghum. These trials are organized by the PCCMCA, an organization among the plant breeding group. Each year a new president and secretary are elected and they are responsible for organizing the trials and making the final report. They also call an annual workshop meeting of about 5 days duration. Entries for the next year are decided at this meeting. Dr. Plant, Dr. Salazar, Ing. Rene and Ing. Pineda (sorghum representatives in Central America) felt this function valuable but ineffective. Seeds do not arrive on time, data is not returned and a report is written about 80% of the time. This is a Central American function not including South America. Through an ICRISAT regional center, possibly more organization could be evolved. The regional center could service the PCCMCA sorghum program and use this as a vehicle for regional evaluation. It could help to expand this program to include disease and insect nurseries.

In conclusion, Guatemala is close to Mexico and Dr. Plant realizing ICTA's narrow base germplasm in sorghum, was quite warm in extending an invitation for cooperative work with ICRISAT. My valuable visit to Guatemala with Dr. Plant made me gain greater appreciation of sorghum, its uses, problems in the highland and lowland tropical countries. ICTA offered land facilities for screening elite germplasm as well as to evaluate special traits such as tolerance to grain mould, anthracnose, etc. There was a great excitement and interest in evaluation more tortilla type cold tolerant materials. The material sent from CIMMYT to Guatemala produced seed at 2000 meter elevation.

The following contacts were made in Guatemala:

1. Ing. Agr. Mario Martínez G.
   General director - ICTA
   Edificio El - Cortez 3er. Piso
   5a. Avenida 12-31 Zona 9 Guatemala C.A.

2. Ing. Carlos Crisostomo
   Technical director - ICTA

3. Dr. Waugh Robert K.
   General director R.F. - ICTA
   Tel. office: 66985, 67935, 310581
   Home: 65791

4. Dr. Albert N. Plant
   National sorghum coordinator - ICTA
   Tel. Home: 690734

5. Dr. Ricardo Bressani
   INCAP
   Guatemala C.A.

El-Salvador: February 11 to February 18

Much of the agricultural development in El Salvador is undertaken by an agency identified as CENTA*. CENTA is a relatively mature organization, dating from 1942. It is basically a research and extension organization dealing with research, credit, fertilizer, herbicides, pesticides, and certified hybrid seed.

CENTA is organized into four groups - a management and administration group and three divisions of research, extension, and seed technology. The Division of Research is constituted by the eight departments of field crops and horticulture, soils, parasitology, animal sciences, agricultural chemistry, agricultural engineering, agricultural economics, and biometrics. Seed technology has three departments, production, certification and processing plants.

CENTA has demonstrated the viability of hybrids in a small-farm agriculture, but is enthusiastic about some new synthetic corns. Its S-1 sorghum is having some difficulties in the market, although its proving popular in Guatemala's eastern area because of its value in tortillas for home consumption. The country's first hybrid sorghum is expected to be released soon. The private trade deals mainly in corn. CENTA aims to build a demand for sorghum that would justify entry of the private industry.

There is a multiple cropping program. There are several basic combinations of crops used in the country; one of the more important sets is corn and beans in the first cycle (of the rainy season) and poll beans (growing on corn stalks and either sorghum or sweet potato during the second cycle. There is a feeling in CENTA that the availability of suitable varieites that better fit the cropping systems was a major limitation.

Several points are worth noting:

1. Sorghum is an important crop in their country.

2. There is an active hybrid seed industry with a quality control program and sorghum hybrids are being developed for farmer use.

3. Multiple cropping is important, sorghum constitutes part of the cropping system, and a major constraint is the availability of suitable varieties to fit the cropping systems. It seems that El Salvador is a country with which ICRISAT might well cooperate.

* CENTA - Centro Nacional de Tecnologia Agropecuaria

Actual situation of grain sorghum in Salvador

Grain sorghum acreage has experienced a constant gain since 1963. Acreage increased from 107,603 ha. to a present acreage of approximately 124,950 ha. Over the same period, yields have experienced a slight increase and this no doubt explains in part the static yield level of the area for example, going from 1.05 ton/ha in 1966-67 to 1.23 ton/ha in 1977. A favourable trend, however, away from the local varieties to improved hybrids does exist.

Surface area, national production, and yield of grain sorghum in Salvador

| Year | Surface area Hectar | National production Tons | Yield Tons/ha |
|---|---|---|---|
| 1966-67 | 107,603 | 113,084 | 1.05 |
| 68 | 103,880 | 106,596 | 1.02 |
| 69 | 113,750 | 122,481 | 1.08 |
| 70 | 113,802 | 126,286 | 1.11 |
| 71 | 124,180 | 145,138 | 1.17 |
| 72 | 126,000 | 154,224 | 1.22 |
| 73 | 130,480 | 143,791 | 1.10 |
| 74 | 119,000 | 154,224 | 1.29 |
| 75 | 129,400 | 129,276 | 1.02 |
| 76 | 132,370 | 172,368 | 1.30 |
| 77 | 124,950 | 154,187 | 1.23 |

The bulk of this acreage is located in areas where the climate and environment is less favourable for corn. Production in these areas is concentrated on small farm units and in excess of 80% is seeded in association with either corn or beans. Forty to fifty percent is destined for human consumption directly as tortillas. Therefore a good starting point would be to improve the yield of the local varieties and to show nutritive improvements since the human consumption of sorghum accounts 50% of its use in El-Salvador. Present improved types and the results of efforts with the new high lysine germplasm from Texas A&M and Purdue can be of real value. A greater breeding effort to utilize the best germplasm as regards day length, wet-dry extremes, and the accompanying insect and disease problems seems in order.

Based on my survey in El-Salvador, the following answers were obtained from the Sorghum team at CENTA. (Ing. Rene Clara - head of the team).

Q. Is sorghum grown in your country or region?

A. Yes.

Q. Could sorghum be grown in some part of the country which is presently not cultivated or replace other crop? Name possible regions.

A. North East of Salvador
North West of Salvador.

Q. Do you import grain sorghum?

A. No.

Q. Name the region where sorghum is grown, and at what elevation.

| A. Regions | Elevation |
|---|---|
| North East area | 0-1000 |
| North West area | 0-1000 |

Q. Present acreage cultivated with sorghum.

A. 124,950 hectares.

Q. Date of planting.

A. May - at elevation 300-700 m. 80% plant in May.
August - at elevation 300-700 m. 20% plant in August.
The reason is because of the differences in the rainfall distribution.
They use the local variety criello.

Q. Date of harvesting

A. January in both case planted with the local variety.
August if planted with hybrid in May (20%)

Q. How many generations can you possibly get per one year.

A. Two generation in the dry regions.
Three to four generations with early maturing coupled with irrigation in the dry seasons.

Q. Do farmers grow hybrids or varieites?

A. Big farmers grow hybrids. 20%
Small farmers grow varieties. 80%

Q. If Hybrids - who produces them?

A. CENTA - SH-500

Q. Where did they get their A and B lines?

A. Texas A&M and MEXICO.

Q. Average range of maturity days of hybrids, and Av. yield.

A. Maturity: 95-98 days, Av. yield 5.4 Tons/hectar.

Q. What is the seed colour?

A. Red pericarp, with no testa, and endosperm semi-crystallin.

Q. Who buys them?

A. Farmers - To plant and feed animals.
Private companies.

Q. Grown for food or feed?

A. For feed.

Q. Any major problems with hybrids.

A. Low yield, nicking problem of A and R lines, and the available A line does not have a good seed set.

Q. If variety: who produces them?

A. CENTA

Q. What is the breeding technique used to extract all varieties?

A. Introduction, (from CIMMYT)
Pedigree - (crosses made at Poza Rica)
Population - (From CIMMYT, LTPA and PRRR Porto Rico)

Q. Av. maturity days for local varieties and Av. yield.

A. May - January 210 days planted in association with corn.
August - January 150 days.
Av. yield 1.3 tons/hectare

Q. What is the seed colour?

A. White

Q. Grown for food or feed?

A. For food 40%
For feed 60%

Q. If used more for feed do you think producing better food type would be necessary?

A. Yes.

Q. Any major problems with the existing varieties?

A. Low yield, late, photoperiod sensitive, small head, compact head, itches while threshing, small seed 10% protein, protein quality poor, but grain quality for tortilla is acceptable.

Q. Specify regions where hybrids and varieties are grown.

A. Coast - mainly hybrids about 5600 ha.
North East and west region - mainly varieties.

Q. Any insect problem? Including bird damage.

| A. Scientific name | Common name |
|---|---|
| Contarinia sorghicola | Midge |
| Laphigma fruigiperda | Full army worm |
| Diatrea linolata | Sugarcane stalk borer |
| | Bird |

Q. How are you handling the problem?

A. Midge - Apply 3-5 gr Furadan/5 m during planting and spray Loebaycid-50 at flowering.
Fall army worm - use Lannate, or volatron granual.
Stalk borer - use volation liquid or granual (Note liquid better).
Bird - Bagging and man control.

Q. What stage and kind of damage done to the plant?

A. Midge - During flowering and as a result grain fails to develop. (Note there will be 100% damage of flowering occurs in July or December)
Fall army worm - from seedling to boot stage and they chew on the leaves. In dry seasons damage will be 90% while in the wet season damage will be 40%.

Q. Any disease damage?

A. Yes, but not of economical problem.

| Scientific name | Common name |
|---|---|
| Sclerospora sorghi | Downy mildew |
| Colletotrichum graminicola | Anthracnose |
| Glococercospora sorghi | Zonate leaf spot |
| Cercospora sorghi | Grey leaf spot |
| Head blight | Seed mould |
| Helminthosporium turcicum | Leaf blight |

Q. How are you handling the problem?

A. a) Pathologist at CENTA is selecting varieties resistant to these diseases by artificial inoculation

Note: He needs to be trained in Texas A&M for a short course. His English is excellent.
Name: Mr. George Clayton Wall.
Note: Ciba Geigy discovered a fungicide (Ridomil) to control powdry mildew.

b) Resistant varieties through breeding.

Q. What stage and kind of damage done to the Plant?

A. All after flowering, that is why they are not very serious.

Q. Is sorghum a staple food crop in your region?

A. Yes, second after maize.

Q. In which form/s sorghum is consumed in your region?

A. Tortilla - local bread name.

Q. Please write the local name/s of the food preparation/s.

A. Tortilla.

Q. What is the detail procedure to prepare the local food/s.

A. Place in a container 12.7 kg. sorghum grain, 58 gr cal (Cao) white powder and add water to cover the seed.
Place the container on a fire for 30 min. and then let cool for 15 minutes.
Remove seed coat by rubbing against your hands and seed coat will float on the surface.
Grind the seed while wet to make a dough (masa)
Then make tortilla or pupusa (two layer tortilla with cheese or meat in between.)
Then place on hot plate on fire for 5 minutes and then ready to eat.

Q. Which cultivar/s of your region is known to make the best food/s?

A. Criollo for tortilla making.

Q. What are the physical or apparent characters of the grain that enable the cultivar/s named in making the particular food/s?

A. White seed coat, absence of testa i.e. tannin, no other pigmentation, vitreous endosperm, absence of mould, palatable, and 50% amylopectin and 50% amylose.

Q. How is sorghum grain utilized in your region, apart from human consumption?

A. Feed (concentrate) for animals.
Dual purpose sorghum - grain and forage.

Q. Latitude

A. 13-14$^{o}$

Q. Soil type

A. Heterogeneous, generally silky loam.

Q. Soil pH

A. 5.5 - 7.0

Q. Rainfall distribution

A. Not uniform - bimodal

Q. Amount of precipitation/yr. mm.

A. Wet areas - 1600-1800 m/yr.
dry areas - 1200-1400 mm/yr.

Q. Day length-

A. Summer - May - November 12.5 hrs/day
Winter - November-April 11.5 hrs/day

Q. Nutrient deficiencies in the soil-

A. Nitrogen, phosphorus, sulfur and magnesium.

Q. Rate and kind of fertilizers applied

A. N-P-K 20-20-
Ammonium sulfate, triple superphosphate.

Q. Irrigated or dryland

A. Dryland

Q. Any frost during growing season

A. Between 0-1800 mm - No
Between 1800-2500 yes in December and January.

Q. Length of growing season

A. 7 months

Q. Lowest temperature in the growing season

A. 13°C at 400 m elevation

8°C at 1000 m elevation

4°C at 1800-2500 m elevation.

Note: On high land coffee is planted, however; they indicated highland areas where coffee is not planted and cold tolerant sorghum could be planted. Estimated area = 600 hectares for small farm situation.

Q. What is the most limiting factor the farmer is facing in each location?

A. Drought.

Q. How strong is the link among?

Private institutions, seed companies, universities, and government research center.

A. Among CENTA, DGG (Direccion General de Ganaderia) and DGRNR (Direccion General de Recursos Naturales Renovables) is good and have joint projects But with the university the cooperation is weak.

Q. Were you cooperating with CIMMYTs sorghum program?

A. Yes.

Q. Were the material useful and adapted in your area?

A. Yes, both lowland and highland.

Q. Do you think Mexico could be used as a center to send breeding material to Latin America?

A. Yes.

Q. Give reasons

A. Materials sent from CIMMYT to Salvador were adapted.

Q. Where do you suggest the center to be

A. Mexico

Q. Are you interested in cooperating with ICRISAT?

A. Yes.

Q. How ICRISAT can best relate and help make a contribution in Central and South America?

A. Help diversify the material.
Training of personnel
Visiting scientist to help improve the program
Send publications, newsletter, sorghum literature on small cards.
Supply with insect and disease resistant different genotypes.

Q. Comments

A. a) They have already received breeding materials from ICRISAT and were very useful. However, in the future, materials with good quality for food having insect and disease resistances will be very useful.

b) They are not doing any research on cold tolerant sorghum, and they have approximately 600 hectares land available for small farmers, so any material developed by ICRISAT as cold tolerant for human consumption would be useful. There are no vast areas of highland in Salvador because coffee, vegetables and fruit trees are grown. Note: They need earlier cold tolerant lines for the highlands.

In conclusion, Salvador is close to Mexico and Ing. Rene Clara mentioned that CENTA's germplasm base in sorghum is narrow; he was quite warm in extending an invitation for cooperative work with ICRISAT. My valuable visit to Salvador with René Clara made me gain greater appreciation of sorghum, its uses and problems in the lowland and highland areas. CENTA has the best research facilities among the Central Latin American countries. They supplied me with 28 A and B lines and their best tropically adapted R lines. Cooperative joint projects between CENTA AND ICRISAT were discussed with the sorghum group and very soon I should be able to supply them with new breeding materials. Many of the materials sent from Poza Rica to Salvador were quite adapted to the lowlands of Salvador and two of their released varieties CENTA-1 and CENTA-2 came from Poza Rica.

The following contacts were made in Salvador.

1. Ing. Rodolpho Crystales (speaks good English)
General director - CENTA
San Andres
La Libertad
El Salvador C.A. Phone 281066

2. Mr. Mario Apontes Martinez
Assistant director

3. Ing. Roberto Vega Lara
Cereal Tech. Chief
Tel: 216252

4. Ing. René Clara
   Sorghum Breeder
   Note: He had training in sorghum breeding at CIMMYT and he feels that ICRISAT could help him increase his knowledge in sorghum breeding, genetics and statistics. I strongly recommend him and suggest that ICRISAT should look after this bright and aggressive young fellow. He is interested to go to ICRISAT and gain some experience. He does not speak good English but promised me to take private course in English.

5. Ing. Rogelio Humberto Cordova
   Sorghum breeder
   Note: He is René's assistant and the director suggested that he will be a good candidate for training at CIMMYT or ICRISAT. He does not speak English.

6. Mr. George Clayton Wall
   Pathologist
   Note: He asked for short intensive training in pathology at ICRISAT or Texas. He speaks Good English.

7. Pedro Antonio Aranjo Yeloa
   Agronomist

8. Napoleon V. Casamalhuapa
   Agronomist

9. Ing. Rogelio Humberto Cordova
   Sorghum seed production
   Note: Needs short course training on seed production. Texas could be a possibility.

10. Ing. Ricardo Dominguez Valladares
    Seed certification chief

11. Dr. Gloria Ruth Calderón
    In charge of quality lab.

Nicaragua:

Nicaragua lies between Honduras (North) and Costa Rica (South). Running parallel to the Pacific Coast of the nation is a central chain of volcanic mountains which offers a variety of climates normally classified according to the thermal zones and determined by elevation. The mean annual temperatures are 78°F at sea level and, about 67°F at 4,500 feet of elevation.

Research in Nicaragua is undertaken in the organization "Institute Nicaraguense de Tecnología Agropecuaria (INTA). INTA developed from a reorganization of the agricultural sector, the movement beginning in 1967. There were two principal goals: increased food production, especially of the basic grains, and to stimulate rural development.

INTA will have as main objectives research, to provide new technology to the farmers and to prepare personnel available to support the agricultural and animal husbandry for the country according to the rules set by the executive power through the ministry of agriculture and livestock. In order to obey this law the institute will orient the actions in the following ways:

a) The objectives set by the institute will contribute to increase the rural sector productivity and increase the diversification for the agricultural livestock and rural industry production. The investigation will be carried out at the regional level according to ecological characteristics.

b) The objective of the extension service will be accomplished through timely transmission of the research results which will be given by the extension agentsof INTA. Improved seeds, animal genetic stocks, or other inputs will be sold to farmers through INTA.

c) By extending education to the rural areas.

Future Program

Basic grain production in Nicaragua is mainly carried out by small farmers, therefore there is low productivity, traditional system and low income.

As the rural diet is mainly constituted by cereals and because 53% of this area is planted with cereal, INTA will perform an integrated program in basic grain. Maize, legumes, sorghum and rice.

Sorghum is similar to maize in its nutritive values so it is used for animal feeding. Yield is 11% higher than corn. One of the more favourable characteristics of sorghum is its relative resistance to drought. The planted area is about 80.000 mZ with an annual production of 1.2 million of quintals in another words the yield is 15 qq/mZ.

Sorghum crop covers the internal needs and last year exports were close to 1.6 million U.S. dollars. INTA has research stations in sorghum in Pacific Central (Experimental station of Managua and Jinotepa) and Interior Central (experimental station San Ramón, and Jinotega).

Activities in sorghum

a) Plant breeding
b) Seed certification
c) Crop management

Specific areas

a) To evaluate commercial varieties and hybrids for human consumption particularly as it applies to small farm situations.

b) To evaluate new introduced lines.

c) To study the ecological condition.

d) To evaluate resistant varieties to midge and to charcoal rot.

e) N.P.K. fertilization practices.

f) Mechanical control of weeds.

g) To evaluate intercropping sorghum with legumes.

h) To evaluate production technology.

INTA carries out investigations on a regional level according to ecological characteristics. The following are the regions, locations, agencies and experimental stations:

| Region | Locations | Agencies | Experimental stations |
|---|---|---|---|
| I | North Pacific | Somotillo | |
| | | El Sauce | |
| | | Chinadega | |
| | | León | |
| II | Central Pacific | Managua | Masatepe |
| | | Masaya | Campos Azules |
| | | Masatepe | Plantel Central |
| | | Granada | |
| | | Jinotepe | |
| III | South Pacific | Rivas | |
| | | Ometepe | |
| IV | Interior North | Jalapa | |
| | | Ocotal | |
| | | Somoto | |
| V | Interior Central | Pueblo Nuevo | Regional Valle de Sébaco |
| | | Esteli | " " |
| | | Matagalpa | Regional Investigacion |
| | | San Ramón | |
| | | Matiguas | |
| | | La Trinidad | |
| | | Raiti | para el pequeno agricultor |
| | | Jinotega | INTA-INIERNO |
| | | | Regional Bonetillo |

| Regions | Locations | Agencies | Experimental stations |
|---|---|---|---|
| VI | Interior South | San Carlos<br>Boaco<br>Juigalpa<br>Santo Tomas<br>San Miguelito | |
| VII | Atlantic North | Andrés Tara<br>Waspam<br>Wasaba<br>Rosita<br>Cabo Gracias a Dios<br>Cruz R. Grande Sinuna<br>Rancho Grande | |
| VIII | Atlantic South | Nueva Guinea I<br>Laguna de Perlas<br>Nueva Guinea 2 | Regional "El Recreo"<br>Nueva Guinea |

Within INTA, Dr. Oscar Hidalgo Salvatierra is the director (speaks good English) and Ing. Laureano Pineda Lacayo is the head of department of cereal, (speaks fair English). Both of them made my visit in Nicaragua very fruitful and strongly favoured ICRISAT's collaboration in Nicaragua.

## Actual situation of grain sorghum in Nicaragua

Grain sorghum acreage has experienced a constant gain since 1960. Acreage increased by 10%, and over the same period, yields have experienced a considerable gain. National production has increased from 847.000 quintals to 1.200.000 quintals (1 ton = 22 qq).

Surface area, National Production, and yield of grain sorghum in Nicaragua

| Year | Surface Area Hectare | National Production Tons | Yields Tons/ha. |
|---|---|---|---|
| 1960-61 | 50,400 | 38,469 | 0.763 |
| 1962 | 54,530 | 49,358 | 0.903 |
| 1963 | 55,790 | 48,495 | 0.867 |
| 1964 | 41,160 | 41,223 | 0.999 |
| 1965 | 40,880 | 46,586 | 0.970 |
| 1966 | 53,270 | 48,859 | 0.915 |
| 1967 | 50,540 | 48,313 | 0.954 |
| 1968 | 52,220 | 51,086 | 0.976 |
| 1969 | 55,020 | 57,130 | 0.998 |

| Year | Surface Area Hectare | National Production Tons | Yields Tons/ha. |
|---|---|---|---|
| 1970 | 47,670 | 51,222 | 1.072 |
| 1971 | 41,370 | 44,405 | 1.071 |
| 1972 | 43,190 | 45,645 | 1.055 |
| 1973 | 37,800 | 37,301 | 0.985 |
| 1974 | 41,860 | 43,677 | 1.041 |
| 1975 | 58,170 | 56,131 | 0.963 |
| 1976 | 59,780 | 62,103 | 1.037 |
| 1977 | 56,000 | 54,540 | 0.972 |

The bulk of this acreage is located in areas where the climate is less favourable for corn. In these areas, the yield of grain sorghum is usually 15-25% superior to corn.

Based on my survey in Nicaragua, the following answers were obtained from Ing. Laureano Pineda:

Q. Is sorghum grown in your country?

A. Yes

Q. Could sorghum be grown in some part of the country which is presently not cultivated or replace other crops. Name possible regions.

A. Central Pacific - Interior Central
South Pacific - North Pacific.

Q. Do you import grain sorghum? Where from.

A. Yes they do import hybrid seeds from U.S.A. especially in some years when corn and sorghum yields are low.

Q. Name the regions where sorghum is grown and at what elevation.

A.

| Regions | Elevation |
|---|---|
| Central Pacific | 50 meters |
| North Pacific | 50-70 m |
| South Pacific | 50-70 m |
| Interior Central | 300-800 m. |

Q. Present acreage cultivated with sorghum.

A. Approximately 60,000 hectares.

Q. Date of planting.

A. May - June
(wet season)
August - September
January - February (dry season)

Q. Date of harvesting.

A. August
December-January
March.

Q. How many generations can you possibly get per year?

A. Two generations planted in May - August
August - December
Three generations provide irrigation is used from January to March

Q. Do farmers grow hybrid or variety?

A. Big farmers grow hybrid.
Small farmers grow varieties.

Q. If hybrids - Who produces them?

A. U.S. seed companies, Dekalb and Pioneer.

Q. Average range of maturity days of hybrid, and Av. yield.

A. 85-110 days to maturity
2500 kg/ha.

Q. What is the seed colour?

A. Bronze, Red, Yellow, and brown.

Q. Who buys them?

A. Big farmers and small farmers and feed mills.

Q. Grown for food or feed?

A. Feed.

Q. Any major problems with hybrids.

A. Low yield. Farmers have not realized yet the full potential of hybrids. Technology and cultural practices are lacking.

Q. If varieties: who produces them?

A. INTA.

Q. What is the breeding technique used to extract all varieties?

A. Selections from introductions, and populations.

Q. Av. maturity days for local varieties, and Av. yield?

A. 100 days to maturity.
400 kg/ha sorghum (criollo) grown in association with corn.
2000 kg/ha new sorghum varieties not grown in association.

Q. What is the seed colour?

A. White without a testa - criollo and Nicapur.
Guatecaw has a testa

Q. Grown for food or feed?

A. Criollo and C-42-4 hybrid (yellow endosperm) grown for food and the extra for feed.

Q. Any major problems with the existing varieties.

A. Low yield, late tall, photoperiod sensitive (Criollo) and Guatecaw has testa, tight head, chalky endosperm, storage and field deterioration.

Q. Specify regions where hybrids and varieties are grown.

A. Central Pacific
(20% hybrids)
Pacific Coast
Interior North (80% varieties) 40% association
Interior Central 40% alone

Q. Any insect problem? Including bird damage.

A.

| Scientific name | common name |
|---|---|
| Contarina sorghicola | Midge |
| Laphigma frugiperda | Fall army worm |
| Diatrea lineolata | stock borer |
| Gusano alambre | wire worm |
| | birds |

Q. How are you handling the problem?

A. Midge - spray 48% Methyl Parathion (cheapest), Diazinon, or Servin.
Fall army worm - spray with Lorsban E 480
Stock borer - Difficult to control.
Wire worm - Furadan 5-G.

Q. What stage and kind of damage done to the plant?

A. Midge - During bloom - grain fails to develop
Fall army worm - From seedling to flowering - Destruction of the vascular tissue
Stalk borer - During grain falling - breakage of the stalk
Wire worm - seedling stage. Attack the roots.

Q. How are you handling the problem?

A. The use of insecticides.

Q. Any disease problem?

A.

| Scientific name | common name |
|---|---|
| Macrophomina phaseoli | Charcoal rot |
| Colletotrochum graminicola | Anthracnose |
| Cercospora sorghi | Grey leaf spot |
| Head blight | seed mould |

Q. How are you handling the problem?

A. Incorporate resistances into the adapted varieties and hybrids.

Q. What stage and kind of damage done to the plant?

A. Charcoal rot is the most serious disease and takes place at flowering and onward while other diseases occur after flowering and are not of economical importance.

Q. In which form/s sorghum grain is consumed in your region?

A. Tortilla and drink (Tiste).

Q. Please write down the local name/s of the food preparation/s.

A. Tortilla (bread)
Tiste (drink)

Q. What is the detailed procedure to prepare the local foods?

A. Tortilla - The same procedure as discussed before.
Tiste - Grind the seed very fine and place in a cup, and some sugar and cacao.

Q. Which cultivar/s of your region is known to make the best food/s. Please write the names of these varieties out the food that it suits the best.

A. Criollo and possibly Nicapur.

Q. What are the physicla or apparent characters of the grain that enable the cultivar/s named in making the particular food/s?

A. Crystallin and white without a testa layer.

Q. How is the sorghum grain utilized in your region, apart from human consumption? Please write specific grain quality requirements, if any.

A. Used as feed and prefer red or bronze colour.

Q. Latitude

A. 10-15$^{0}$

Q. Soil type.

A. Pacific coast - sandy loam
Central Pacific - Volcanic heavy soil.

Q. Soil pH.

A. 6.7 - 7

Q. Rainfall distribution

A. Not uniform with a dry period in August.

Q. Amount of precipitation/yr. mm.

A. 500-5000 mm/yr. Av. 1000-1500 mm/yr.

Q. Day length

A. Summer-May-August 12 hr. August to Dec. 11 hrs
Winter - January-May 12.5 hrs.

Q. Nutrient deficiencies in the soil.

A. N, P, K.

Q. Rate and kind of fertilizers applied.

A. 100 lb N/M2 (urea 46%) or 10-30=10 at planting and 2.5 qq/m2 N as side dressing.

Q. Irrigated or dryland

A. May - Dec - dryland
January - May - irrigated.

Q. Any frost during the growing season

A. No.

Q. Length of growing season.

A. May - December.

Q. Lowest Temperature in the growing season.

A. 17°C.

Q. What is the most limiting factor the farmer is facing in each location?

A. Technical information.

Q. How strong is the link among?
Private institutions, seed companies, universities, and government research centers.

A. Good

Q. If there is any coordination - what sort?

A. Testing each others material and exchange knowledge.

Q. Do you think Mexico could be used as a center to send breeding material to Latin America.

A. Yes.

Q. Give reasons.

A. Good relation with CIMMYT.

Q. Where do you suggest the center should move?

A. CIAT Colombia and have a substation at El Salvador CENTA.
Note: Dr. Angel Salazar working for Dekalb mentioned that sorghum materials received from Colombia were not adapted in Nicaragua probably because they were not tested on a regional basis. He strongly suggests that ICRISAT should be working very closely with PCCMCA.

Q. How is the program run and where didyou get your breeding materials from?

A. Texas A and M., and PCCMCA.

Q. Are you interested in cooperating with ICRISAT?

A. Yes.

Q. How ICRISAT can be relate and help make a contribution in Central and South America?

A. 1 - send breeding materials to diversify our gene pool, and also to supply us with adapted varieties, or population for human consumption.
2 - Materials with disease and insect resistances.
3 - Training personnels in sorghum breeding.
4 - ICRISAT should participate closely in the PCCMCA testing.

Comments

Sorghum is used in Nicaragua as follows:

85% as animal feed.
8% for human consumption.
4% loss due to bird damag .
1.4% saved for planting.
1.6% for export.

Candidate recommended by the Director General for sorghum breeding: Ing. Emilio Lexpon L. (He does not speak English but he promised will take special source in English).

They need cold tolerant material food type (Tortilla) to be tested on high elevation in Matagalpa (1700 m).

They need for the arid regions Madriz and Stels drought resistant sorghum varieties or hybrids for human consumption.

They need a sorghum variety with 70-80 days of maturity to plant in cotton fields (250,000 ha).

In conclusion, Nicaragua realizing the future of sorghum and coupled with their narrow base germplasm in sorghum, was quite warm in extending an invitation for cooperative work with ICRISAT. My valuable visit to Nicaragua with Ing. Laureano Pineda and Dr. Oscar Hidalgo made me gain greater appreciation of sorghum, its uses and problems in the highland and lowland areas.

The following contacts were made in Nicaragua:

1. Dr. Oscar Hidalgo Salvatierra (speaks good English)
INTA (Instituto Nicaraguense de Tecnologia Agropecuaria).
Km. 12 Carretera Norte.
Apdo. - 592
Managua, Nicaragua C.A.
Cable address - INTA - Apartado 2648
Managua, Nicaragua.
Phone 3717 or 3780 ext. 261.

2. Ing. Laureano Pineda Lacayo (speaks fair English)
   The same as above.

3. Dr. Angel Salazar (speaks good English)
   Apdo. 3242 (Dekalb)
   Managua, Nicaragua C.A.
   Tel. 8643.

4. Ing. Emilio Leypon L.
   The same as above INTA.

5. Dr. I. Arnoldus Van Huis (speaks good English)
   FAO - Integrated Pest Control
   At. Post 1524
   Managua, Nicaragua C.A.

6. Dr. Rainer Daxl
   FAO Ecologist officer
   Apdo. 3260
   Managua, Nicaragua

7. Mr. Rymond Gross and Ing. Pedro Comalat R. (Pioneer)
   Apdo. 13 - Chinandega
   Managua, Nicaragua C.A.
   Tel. 3142.

Colombia:

Research on sorghum in Colombia is undertaken in the organization "Instituto Colombiano Agropecuario" (ICA). ICA's two principal goals are:

1. To increase food production, especially of the basic grains (which includes sorghum).

2. To stimulate rural development.
ICA has a direct responsibility for creating, identifying, generating technology, testing it under conditions where it will be used, and adapting it to those same conditions.

Within ICA Dr. Manuel Torregroza is the national maize and sorghum coordinator stationed in Bogota made my visit in Colombia very fruitful and strongly favoured ICRISAT's contribution in Colombia in the near future.

Within CIAT in Cali Dr. John L. Nickel (General Director), Dr. Kenneth O. Rachie and Dr. Alexander Grobman (outreach Director) welcomed ICRISAT in CIAT as far as fitting in the system. CIAT is also interested in seeing efforts to improve sorghum enhanced. If ICRISAT wishes to pursue ties with this part of the world both of these organizations might be contacted.

Agreements are being negotiated with the Instituto Colombiano Agropecuari (ICA) for a new form of collaborative system, which takes into consideration the new scope, content, and objectives, contents and rearrangement of program, and their location resulting from the evolution of policies at ICA. The approach followed is by station operations, as well as by commodities. A finalized agreement or set of agreements will be completed in 1977.

Actual situation of grain sorghum in Colombia

Grain sorghum acreage has experienced a constant gain since 1962. Acreage increased from 3.3 thousand hectares to a present acreage of approximately 174 thousand hectares over the same period, yield have experienced a considerable gain.

Surface area, national production, and yield of grain sorghum in Colombia

| Years | Surface Area Hectares | National Production Tons | Yield Tons/ha |
|---|---|---|---|
| 1962 | 3,300 | 7,600 | 2.3 |
| 1963 | 5,400 | 12,100 | 2.2 |
| 1964 | 24,000 | 60,000 | 2.5 |
| 1965 | 30,000 | 70,000 | 2.3 |
| 1966 | 35,000 | 80,000 | 2.3 |
| 1967 | 40,000 | 90,000 | 2.3 |

| Years | Surface Area Hectares | National Production Tons | Yield Tons/ha |
|---|---|---|---|
| 1968 | 49,000 | 110,000 | 2.2 |
| 1969 | 45,000 | 100,000 | 2.3 |
| 1970 | 54,000 | 118,000 | 2.2 |
| 1971 | 92,000 | 240,000 | 2.6 |
| 1972 | 84,000 | 210,000 | 2.5 |
| 1973 | 135,000 | 280,000 | 2.1 |
| 1974 | 151,000 | 337,000 | 2.2 |
| 1975 | 134,000 | 335,000 | 2.5 |
| 1976 | 174,000 | 428,000 | 2.5 |

CIAT scientists conduct primary research at four centers in Colombia; at CIAT; headquarters near Palmira, at the Turipana and Carimagua research stations of the Instituto Colombiano Agropecuario (ICA); and the Popayan research station of the Secretaria de Agricultura del Cauca. In addition, testing is done at many other locations throughout Latin America.

The climate at Palmira, in the Departmento del Valle, represents a typical equatorial upland environment with a bimodal rainfall distribution. The comparatively low mean annual rainfall is due to the orographic effects of both the eastern and western cordilleras of the Andes. Negligible seasonal mean temperature variation strongly contrasts with strong seasonal variation in rainfall. The two dry seasons are normally short. July and August are the drier months with NE wind predominating.

The climate at the research site near Papayán, in the Departamento del Cauca, is also representative of equatorial upland climates in other areas of the world. The bimodal rainfall distribution is quite similar to Palmira although rainfall, particularly in the second wet season is much higher.

The climate at Turipana, in the Departamento de Cordoba, is strongly representative of other lowland tropical environments with a unimodal rainfall distribution at sub-equatorial latitudes. The higher mean temperature is a direct reflection of the lower altitude.

The tropical savana climate at Carimagua, Departmento de Meta, is typical of inland regions in the equatorial and sub-equatorial zones with a more or less unimodal rainfall pattern strongly contrasting wet season rainfall and higher temperatures during the dry season.

ICA has 10 active research stations and 5 stations where sorghum research has been initiated. They have 2 research stations on highland 2100m and 2600 Tibaitata in Bogota and Rio Negro respectively.

Based on my survey in Colombia, the following answers were obtained by Dr. Torregroza and Ing. Jozé Moreno at Tibaitata-Bogota.

Q. Is sorghum grown in your country or region?

A. Yes

Q. Could sorghum be grown in some part of the country which is presently not cultivated or replaced other crops?

A. On highland above 1800 m, and on lower elevations where moisture is limiting for corn.

Q. Do you import grain sorghum? where from.

A. Yes, from U.S.A.
Dekalb - Proacol
Pioneer - Semivalle
Asgro - Purina
Northrup King - Cosemilla
Prosemillas.

Q. Name the region where sorghum is grown and at what elevation.

| | Region | Station | Elevation | Scientist |
|---|---|---|---|---|
| A. | Atlantic Coast NW | Monteria | 0-600 m | Ing. Hector Giraldo |
| | | ICA-Turipaná | | |
| | Atlantic coast NW | Valledupar | 0-600 | Ing. Gilberto Gomes |
| | | ICA Motilonia | | |
| | Central Colombia | Tolima | 400 m | Ing. Alvaro Castrillon |
| | | ICA Nataima | | |
| | Central Colombia | Bogota | 2600 m | Ing. José Moreno |
| | | ICA Tibaitata | | |
| | | Río Negro | 2100 m | Ing. Carlos Día |
| | Oriental Region | Meta | | |
| | | ICA La Liberated | 400-500 m | No staff |

Note: Vaupes, Caqueta, Guainea, Vichada regions could grow sorghum but breeding work would have to be done to adapt sorghum to grow at pH 4-5 with AL - Toxicity low fertility, very humid.

Cordillera occidental
" central 2200-2800 about 500,000 ha.
" oriental potential for sorghum.

Lowland oriental N.E. ICA Arsenal 400 m Ing. Carlos Carvajal.

Q. Present acreage cultivated with sorghum.

| | Region | Elevation | Acreage-Hectares |
|---|---|---|---|
| A. | Valle del Cauca | 600 m | 62,000 |
| | Tolima central | 400 m | 52,000 |
| | Atlantic coast | 0-400 m | 38,000 |
| | Oriental region | 0-400 m | 20,000 |

Q. Date of planting

February and March cycle 1
August and September cycle 2 — low elevation

February-March — high land

Q. Date of harvesting

A. June - July
(low elevation)

December-January

Note: Possibility of frost on high elevation in Nov. & Dec.

June - July possibility of frost on highlands in August, September, November, December, January and February.

Q. How many generations can you possibly set per one year?

A. Two generations in lowland.

With early maturing lines supplimented with irrigation you can get three.

Q. Do farmer grow Hybrid or Variety?

A. Both, 59% hybrids and 41% variety.

Q. <u>If Hybrid</u> - Who produces them?

A. U.S.A. seed companies mentioned earlier.

Q. Where did they get their A and B lines?

A. U.S. A and B lines.

Q. Av. range of maturity days of hybrids, and Av. yield.

A. For lowland 110 days Av. yield 2-2.8 tons./ha.

Note: There is a need of hybrids maturing between 80-95 days to grow in rotation with cotton, rice, soybean.

Q. What is the seed colour?

A. Brown.

Q. Who buys them?

A. Farmers to plant and to feed.

Private companies, such as Purina and Finca.

Q. Grown for food or feed?

A. Majority for feed and very little for food because they don't know that it can be used for food.

Q. Any major problems with hybrids.

A. Adaptation, susceptibility to diseases and insects.

Q. If Variety - Who produces them?

A. ICA carried the basic research and seed companies increase them.

Q. What is the breeding technique used to extract all varieties?

A. Introduction, pedigree method and little work on population.

Q. Av. maturity days for local varieties, and Av. yield.

A. ICA Nataima - 110-120 days, Av. yield 2.2 Tons/ha.

Q. What is the seed color?

A. Cafe.

Q. Grown for food or feed?

A. For animal feed.

Q. If used for feed, do you think producing food type would be necessary?

A. Yes, the farmers need to be shown.

Q. Any major problems with the existing varieties?

A. Low yield, photoperiod sensitive (50%), susceptible to midge, fall army worm and stalk borer.

Q. Hybrids vs Varieties

A.

| | |
|---|---|
| Cauca Valley | 60% hybrids and 40% varieties |
| Atlantic coast | 80% hybrids and 20% varieties |
| Central Colombia | 40% hybrids and 60% varieties |
| Central East | 50% hybrids and 50% varieties |

Q. Any insect problem? Including bird damage?

A.

| Scientific name | Common name |
|---|---|
| Contarinia sorghicola | Midge |
| Diatraea lineolata | Stalkborer |
| Laphigma frugiperda | Fall army worm |
| Pyroderces sp. | Celama |

Q. How are you handling the problem?

A. Using chemical insecticide Malathion, Bassudrin, Sevin, Azodrin, Nuvan.
Difficulto control - biological control - use of wasps (Trichogramma sp).
Use of insecticide.
Use of insecticide.

Q. At what stage and kind of damage done to the plant?

A. At flowering
After 80 days
Seedling to flowering
Flowering to physiological maturity

Q. Any disease problem?

A.

| Scientific name | Common name |
|---|---|
| Macrophomina phaseoli | Charcoal rot |
| ? | virus (not known) |
| Colletotrichum graminicola | Stalk & Head Anthracnose |
| Head blight | moulds |

Q. How are you handling the problem?

A. Using resistant varieties and hybrids
" " "
" " "
At flowering apply fungicide - Dithane by plane
- Mansate

Q. What stage out kind of damage done to the plant?

A. After 80 days.
After 20 days.
After flowering.
After grain formation.

Q. Is sorghum a staple food crop in your country?

A. No but very few people use it for food.

Q. In which form/s sorghum grain is consumed in your region?

A. Soup.
Arepa - 10-15 cm diameter and 1 cm thick bread.
Chicha - fermented drink.

Q. Please write the local name/s of the food preparation/s.

A. Sopas
Arepa
Chicha

Q. What is the detailed procedure to prepare the local food/s.

A. Sopas - Boil seed with water + Ca.O remove seed coat, grind wet and put in a container with meat and spices.
Arepa - Soak seed with Ca.O overnight, then grind wet, make a dough and bake.
Chicha - Boil with Ca.O, grind wet, place in a jar, and brown sugar, mix cover and let stay for 3 days and then drink.

Q. Which cultivar/s of your region is known to make the best foods.

A. We don't have a good variety yet. These foods are prepared from maize but food type sorghum could be used to prepare these foods.

Q. How is sorghum grain utilized in your region, apart from human consumption?

A. Animal feed, seed color cafe BR64.

Q. Latitude

A. $4^{o}$ - $12^{o}$.

Q. Soil type.

A.

| | |
|---|---|
| Valle del cauca | silty clay |
| Tolima | Sandy loam |
| Coast Atlantic | Sandy loam or silty loam |
| Oriental region | Sandy loam |

Q. Soil pH

A. pH 6 - pH 7 while in Meta region pH 4.5

Q. Rainfall distribution

A. Not uniform

Q. Amount of precipitation/yr mm.

A. 800 mm - 1500 mm

Q. Day length

A. Summer
Winter 12 hrs.

Q. Nutrient deficiencies in the soil

A. N, P, Bo, Zn.

Q. Rate and kind of fertilizers applied

A. N P K - 25, 15, 0 or 15, 15, 15, or 10, 30, 10.
Urea 150 kg/h. 46% in split application.

Q. Irrigated or dryland

A. Dryland

Q. Any frost during growing season

A. Not on lowland
Yes in highland

Q. Length of growing season (days)

A. February - July.

Q. Lowest temperature in the growing season

A. $15^{o}$ C at Palmira.
$20^{o}$ C at Tolima.
$-5^{o}$C on highland.

Q. What is the most limiting factor the farmer is facing in each location?

A. Technology, varieties, and low prices.

Q. How strong is the link among?

Private institutions, seed companies, universities, and government research centers?

A. Good cooperation except that CVC which is semi-autonomous institute have no cooperation what so ever with ICA.

Q. Ware you cooperating with CIMMYT's sorghum program?

A. Yes.

Q. Were the materials useful and adapted in your area?

A. If early cold tolerant materials are developed would be very useful for Colombia.

Q. If the material was not adapted, what was wrong with it.

A. Need earlier lines, white seeded with no testa layer.

Q. Do you think Mexico could be used as a center to send breeding material to Latin America?

A. Dr. S.P. Singh. Yes - Because materials sent from Poza Rica and El - Batan were well adapted in other L.A. countries. Disease and Insect natural incidence are available in Poza Rica. Tlatizapan (900 m) in Mexico is similar to Cali CIAT except that Cali has high pH and drier and less disease incidence, but Cali has more fall army worm natural infestation.

Dr. Nickles. Was quite warm in extending an invitiation for cooperation work with ICRISAT.

Dr. Rachie and Dr. Grobman think that Colombia situation covers all Latin America and that ICRISAT should have a scientist preferably a breeder at CIAT.

Ing. José Moreno. CIMMYT's material from Poza Rica are adapted in the lowland of Colombia but not the high elevation material.

Q. Where do you suggest the center should move?

A. All agreed to have one scientist at CIMMYT and one at CIAT.

Q. How was the program run and when did you get your breeding material from?

A. Mexico, U.S.A. (Texas) and world collection.

Q. Are you interested in cooperating with ICRISAT?

A. Yes. ICA and CIAT both.

Q. How ICRISAT can best relate and help make a contribution in central and south America?

A. Supply the program with breeding materials.
Supply adapted A and B and R lines.
Cold tolerant material.
Training personnel on sorghum breeding
Send ICRISAT's Newsletter
Invite scientist from ICA to participate in ICRISAT workshop.

7. Bogota.

Dr. Manuel Torregroza
ICA - Tibaitatá
Apartado Aereo 151123 El dorado
Bogota - D.E. Colombia.
Tel. Home 2532140 Office: 813080

8. Ing. José Moreno
ICA - Tibaitata
Tel. Home 2733314.

Mexico:

Research in Mexico is undertaken in the organization "Instituto Nacional de Investigacion Agropecuaria" (INIA). Their two principal goals are: Increase food production, especially of the basic grains which includes sorghum. INIA has a direct responsibility for creating, identifying, generating technology, testing it under conditions where it will be used. Within INIA Dr. Carballo C. Aquiles who is the coordinator of the National sorghum program also Dr. Leopoldo Mendoza of Chapingo strongly favoured ICRISAT's future contribution in Mexico and already INIA, Chapingo and ICRISAT/CIMMYT are undertaking 4 projects.

Actual situation of grain sorghum in Mexico

Grain sorghum acreage has experienced a constant gain since 1961. Acreage and yield have experienced a considerable gain, National production has increased over 10 fold.

Surface area, National Production, and yield of grain sorghum in Mexico

| Year | Surface Area Hectare | National Production Tons | Yield Tons/ha. |
|---|---|---|---|
| 1961 | 117,000 | 291,000 | 2.5 |
| 62 | 118,000 | 296,000 | 2.5 |
| 63 | 198,000 | 402,000 | 2.0 |
| 64 | 276,000 | 526,000 | 1.9 |
| 65 | 314,000 | 747,000 | 2.4 |
| 66 | 576,000 | 1411,000 | 2.4 |
| 67 | 665,000 | 1605,000 | 2.4 |
| 68 | 857,000 | 2128,000 | 2.5 |
| 69 | 883,000 | 2453,000 | 2.8 |
| 1970 | 950,000 | 2565,000 | 2.7 |
| 71 | 820,000 | 2335,000 | 2.8 |
| 72 | 1063,000 | 2441,000 | 2.3 |
| 73 | 1185,000 | 3182,000 | 2.7 |
| 74 | 1153,000 | 3183,000 | 2.8 |
| 75 | 1116,000 | 2843,000 | 2.5 |
| 76 | 1180,000 | 3350,000 | 2.8 |

The breakthrough was brought about by the discovery in 1956 by Stephens in Texas of a sorghum plant with cytoplasmic male sterility. The existence of heterosis or hybrid vigour in sorghum crosses had been already demonstrated. The discovery of feasible mechanism for producing $F_1$ hybrid seed in a commercial scale by using a male sterile parent, cytoplasmically sterilized, and a gene restorer male parent, formed the basis of a strong hybrid sorghum

seed business in the U.S. By 1959-60 hybrid sorghum seed production was well on its way as a solid industry in the U.S. and trials in Mexico, Argentina, Australia, and South Africa had proven an amazing fact. U.S. bred sorghum hybrids performed in all those countries exactly as they did in the U.S. while hybrid maize exhibited a high location x genotype interaction in yields, hybrid sorghum did not. This very fact was quickly realized by U.S. seed companies and their early establishment in 1960 in Argentina, and Mexico, countries with large, semi-arid areas, assured the further development of sorghum as a crop in those countries.

In Mexico, sorghum was quickly introduced in the irrigated valleys of the Northwest, in the La Laguna area near Torreón, previously a cotton area. Very quickly, Mexican farmers borrowing U.S. production technology, learned by driving across the border, and watching and talking to U.S. farmers, were obtaining yields equal or higher than in the U.S.

As sorghum production soared in Mexico, the authorities in control of irrigation water in the irrigation districts, realized the great efficiency of sorghum in terms of use of irrigation water. Sorghum in its utilization of water was found to be twice as efficient as cotton, and four times as efficient as rice. Because sorghum could use the same planting and harvesting machinery as wheat, a rotation sequence of wheat-sorghum became firmly established.

A transferable technology of hybrid seeds, and the setting up of mechanisms for seed production, distribution, and demonstration of production technology was due to U.S. seed companies. While prior to 1950, Mexico produced less than 200,000 tons of sorghum, in 1965, production had gone up to nearly 750,000 tons, in 1970 to 2 1/2 million tons and in 1976 to 3.35 million tons. The magnitude of the sorghum production in Mexico has exceeded that of wheat in the rate of growth as well as total production.

It is also interesting to note that the yield of sorghum was nationally 2,839 kg/ha in 1976, as compared to 1,278 kg/ha for corn the same year, and this is in spite of corn research in Mexico for over 30 years.

Sorghum production in Mexico went basically to the feed mills, for production of poultry, hog, and dairy cow balanced feeds, releasing millions of tons of corn from this use, for the direct human consumption by the expanding population of Mexico.

New hybrids are being released which have good resistance to both diseases as well as good agronomic traits. Also, much of the sorghum in central Mexico is or could be grown at altitudes above 1500 m. At present, cold tolerance, which is only partially dominant and thus needed on both sides of the cross, has been transferred into yellow and vitreous white endosperm males and low tannin or non-brown females. Thus, grain hybrids of good nutritive value as opposed to the brown seeded types of the first cold tolerance material are now ready for extensive evaluation.

This brings up another aspect of positive grain improvement for Mexico and also Central America for that matter: much improved nutritive value. In Mexico it is estimated to have 1.3 million hectares available for cold tolerant highland sorghum. Where grain is grown for human consumption, this becomes even more important but could be a factor for acceptance and increased acreage throughout Latin America. In much of Mexico, increase drought resistance can not be stressed enough. Here again the future looks promising. Finally, to expand the crop into new areas, especially to the south, may require a greater use of tropical germplasm.

Based on my survey in Mexico, the following answers were obtained from Dr. Carballo Aquiles.

Q. Is sorghum grown in your country?

A. Yes.

Q. Could sorghum be grown in some part of the country which is presently not cultivated or replace other crop.

A. Yes, in semi-arid high elevation areas.

Q. Name the region where sorghum is grown and at what elevation.

| A. Region | Elevation |
|---|---|
| Bajio and Altiplano de Jalisco | 1550 - 1800 m |
| Tamaulipas | 500 m |
| Sinaloa | 500 m |
| Other regions | 0-1800 m |

Q. Present acreage cultivated with sorghum.

| A. Region | Acreage Hectares |
|---|---|
| Bijio and Altiplano | 730,000 |
| Tamaulipas | 420,000 |
| Sinaloa | 140,000 |
| Other regions | 210,000 |

Q. Date of Planting

A. April or June
February and June
December and July
December and June

Q. Date of Harvesting

A. September and November
July and October
May or November
May or November

Q. How many generation can you possibly get per one year.

A. In the tropical lowland, two generations per year, while in the highland areas only one generation.

Q. Do farmers grow Hybrid or Variety?

A. Both.

Q. If Hybrid who produces them?

A. National seed producers. (PRONASE)
U.S. seed companies

Q. Where did they get their A and B lines?

A. INIA developed their A and B lines.
U.S. seed companies

Q. Av. range of maturity days of hybrids, and Av. yield?

A. 120 to 150 days.
3 tons/ha.

Q. What is the seed colour?

A. Red, brown, amber, white.

Q. Who buys them?

A. Animal feed industries.

Q. Grown for food or feed?

A. For poultry and pigs.

Q. Any major problem with hybrids.

A. Seed production.

Q. If Varieties - who produces them?

A. INIA and Chapingo University.

Q. What is the breeding technique used to extract all varieties?

A. Pedigree Selection
Mutation
Population improvement.

Q. What is the seed colour?

A. Brown, amber, and white.

Q. Grown for food or feed.

A. For animal feed.

Q. If used for feed, do you think producing food type would be necessary?

A. Yes, especially for small farmer situation.

Q. Any major problems with the existing varieties.

A. Low yield and susceptible to diseases and insects.

Q. What percentage of hybrid and varieties are grown in Mexico?

A. 100% hybrids and negligible amounts of varieties.

Q. Any insect problem? Including bird damage.

A.

| Scientific name | Common name |
|---|---|
| Contarina sorghicola | Midge |
| Schezaphis graminum | Aphids |
| Spodoptera frugiperda | Fall army worm |
| Diatrea lineolata | Stem borer |
| | Salema or webworm |

Q. How are you handling the problem?

A. Using resistant varieties.
Date of planting.
Cultural practices.
Insecticides.

Q. What stage and kind of damage done to the plant?

A. Midge - During bloom. Grain fails to develop.
Aphid - After flowering until seed set, lower yield.
Fall army worm. Destruction of the leaves from seedling until flowering.
Stem borer. Destruction of the vascular tissues, at any stage.

Q. Any disease damage?

A.

| Scientific name | Common name |
|---|---|
| Sclerospora sorghi | Downy mildew |
| Sphaulothem sorghi | Charcoal rot |
| Colletotrichum graminicola | Anthracnose |

Q. How are you handling the problem?

A. Using resistant varieties and parents.

Q. What stage and kind of damage done to the plant?

A. Before and after flowering thus lower yield.

Q. Is sorghum a staple food crop in your region,

A. No.

Q. How is sorghum grain utilized in your region, apart from human consumption? Please write specific grain quality requirements, if any.

A. Sorghum grain is mainly used for animal feed and at this stage no attention is given to the quality aspect of monogastric.

Q. Latitude.

A. $16^{o}$ - $32^{o}$ North

Q. Soil type.

A. 1 - Bajio and Altiplano - heavy clay, and sandy loam.
2 - Tamaulipas - sandy loam
3 - Sinaloa - sandy loam

Q. Soil pH

A. pH 6-8

Q. Rainfall distribution

A. Fair to good distribution

Q. Amount of precipitation/yr.

A. 700 - 1000 m.

Q. Day length

A. Summer - 14-15 hrs.
Winter 12 hrs.

Q. Nutrient deficiencies in the soil

A. Nitrogen, phosphorus and iron.

Q. Rate and kind of fertilizers applied

A. N - 80-180 kg/ha.
$P_2O_5$ - 40 kg/ha.

Q. Irrigated or dryland.

A. Both.

Q. Any frost during growing season?

A. In lowland no.
In highland yes.

Q. Length of growing season.

A. Highland 210-220 days.
Lowland 360 days.

Q. Lowest temperature in the growing season.

A. Highland - 6-8°C.
Lowland - 18-20°C.

Q. What is the most limiting factor the farmer is facing in each location?

A. Insects are the most limiting factor and then diseases.
There are other areas with high salinity and iron deficiency and high pH.

Q. How strong is the link among?

A. Private institutions, seed companies, universities and government research centers - Fair to Good.

Q. Were you cooperating with CIMMYT's sorghum program?

A. Yes.

Q. Were the materials useful and adapted in your area?

A. Yes, they were adapted and were used as a base for cold tolerant improvement

Q. Do you think Mexico could be used as a center to send breeding material to Latin America?

A. Yes.

Q. Give reasons in both cases.

A. Because Mexico has very diverse ecological conditions which simulates most of Latin American countries.

Q. Where do you suggest the center should move?

A. It all depends what will be ICRISAT's objective.

Q. How are the program run and where did you get your breeding materials from?

A. The breeding material came from U.S.A.

Q. Are you interested in cooperating with ICRISAT?

A. Yes.

Q. How ICRISAT can best relate and help make a contribution in Central and South America?

A. By supplying INIA with new germplasm with disease and insect resistances.
Carrying out cooperative and joint projects.
Food type breeding material - i.e. grain quality.
By sending us ICRISAT's newsletter and publications.
Training of personnels.

The national program conducted by INIA was initiated in 1946 with the observation of material in the different regions of Mexico to define the adaptation of sorghum.

In spite of staff and budget limitation this program has produced 35 hybrids which had been delivered to National seed producers for its commercial production.

The Research Stations of INIA are:

1. Rio Bravo - Dry, Tropical region - irrigated.
2. Roque Guanajuato - Temperate - rainfed.

The objectives for the highland was started in 1960 and up to the present time according to Dr. Carballo's opinion, it is a major program since it takes into account basic research as well as the different schemes to reach to their short, medium and long term objectives. At the present time varieties are available that potentially could be grown in 1 million hectare. The sorghum program has become a major endeavour with the objectives of supporting activities involved in the generation of production technology including breeding for areas for commercial productions as well as small farm situations where sorghum could be grown and used as food.

At the present time, the program has enough staff and germplasm for conducting research. On this basis, the program is open to any kind of cooperation as long as these cooperations comply with the INIA policies. Particularly, it is important to diversify the sorghum germplasm and to obtain millet germplasm and also to improve the professional quality of the staff through training personnel and attending sorghum workshops and academic training. Any support in the above mentioned points would be of

great help to the Mexican National program. In return INIA is ready to cooperate in coordinated activities that could support other Latin American program.

The following contacts were made in Mexico.

1. Dr. Carballo C. Aquiles (does not speak English)
   INIA (Instituto Nacional de Investigacion Agricola)
   National Sorghum and Millet Coordinator
   Apdo. Postal No. 10 Chapingo, Mexico
   Tel. 585-45-55 office.

2. Dr. Leopoldo Mendoza (Speaks English)
   Genetic department
   Colegio de Postgraduados
   Chapinge, Mexico
   Tel. 585-45-55 ext. 229 or 210 (office)
   4-12-86 (Home)

3. Dr. Hernan Cortéz Mendoza (Speaks English)
   Director of Maize and Sorghum
   Universidad Autonoma Agraria
   Guanajuato 525
   Buenavista, Saltillo
   Coahuila, Mexico
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APPENDIX II

NOTES FROM VISIT TO VENEZUELA, GUATEMALA, AND MEXICO

SEPTEMBER 28 - OCTOBER 6, 1977

L.R. HOUSE

Sorghum is developing fairly rapidly as an important crop in Venezuela. Its more extensive use began about ten years ago and in this period the area under cultivation has increased from 3000 to 120000 hectares. The grain is all used as a livestock feed.

There are a number of situations which must be taken into account. The sorghum regions in Venezuela are essentially three; one in the east around Maturin (1400 mm. rainfall); one in the west near Barinas (1200 mm. rainfall); and the third more or less in the north central part of the country around Valle de la Pascua (600 mm. rainfall). The soils around Maturin are red and sandy (80% sand); around Valle de la Pascua are light brown with fairly high sand content and around Barinas are poor - acid (as much as pH 4.2) with a relatively high but apparently non-toxic level of aluminium. Soils in the other locations also are on the acid side but not as bad. In acid situations it is recommended to use one ton per hectare of $CaCO_3$. Although the rainfall is high there are wet and dry seasons: the dry season extending more or less October-November to May. The sowing date for sorghum is broad extending from June into September.

The sorghums being used are hybrid and any effort to develop something for the farmer will have to be hybrid to contribute with what exists. Research to develop hybrids began with Proseca in 1968 and has more recently begun with the Ministry of Agriculture (1975). There is a very modest breeding program to develop and test new hybrids. The testing program is regional within Venezuela. A number of hybrids have been evolved between seed parents from the USA and pollen parents from tropical Africa, and from Swaziland. This past year 350,000 kilograms of seed were produced which was used on about 10% of the area sown. Seed is in demand and they hope to increase production to 1,000,000 kilograms this next year. Their big problem is to have available good adapted seed parents. Most of the A-lines from the USA that we saw looked terrible and would be at best difficult to get satisfactory yield in production fields.

Commercial companies (Asgrow, Dekalb, Pioneer) import seed of hybrids developed in the USA. Those selected are frequently based on results obtained in Mexico. There is no research or production by these companies in Venezuela. Yield trial results indicate that these company hybrids are lower yielding (1500-200 kg/hectare) than those developed locally.

It seems clear that an ICRISAT program in the Americas should be involved with the development and evaluation of hybrids. The development of good seed parents (A-lines) for the higher rainfall tropical situation would be a real contribution here as well as in Africa.

The desire is for varieties that require about 65 days to flower, one problem with hybrids from the USA is earliness - they flower in about 50 days.

Selection pressure for tolerance to the acid soil situation has been remarkably successful. Hybrids from USA and selected local material will show up to a 17 fold increase in yield when the acid condition is rectified by $CaCO_3$. Locally selected, tolerant hybrids, show only a slight increase and yields of all the treatments are in the high range of the experiment. Apparently, many of the tropical soils in the Americas are acid in nature.

Yields are currently between 2 and 3 tons of grain per hectare from the hybrids. Increase of yield of hybrids over varieties ranges with location from 40% to 100%. Heads are semi-compact to reasonably open and plants are 1.2 - 1.8 meters tall (all harvesting is by combine). Adapted plants have a normal good luxuriance but grain number per head appears to be lower than possible. Scope for increased yield beginning with more intensive introduction particularly from tropical Africa and from material from ICRISAT appears promising.

There is no market preference for grain quality, coloured or white, bitter or sweet, it all sells for 80 Centavos per kilogram (about 19 cents US). Most of the grain produced is coloured and bitter - birds can be a serious problem.

The major problem is variable from year to year depending on whether or not a migratory bird from Texas arrives (species Americana). If the bird comes it takes all seed whether or not its bitter - farmers are forced to harvest before the bird problem becomes that severe. These mibratory birds have not come in the last four years but earlier were severe. In the absence of these birds the damage from local birds is minor unless the field is small or earlier or later than the bulk of the crop. Bitter seeds to help against local birds.

The disease problem is more serious than the insect problem though both are important. The major disease problem is downy mildew and the comment was made that there is no point considering a breeding program without including resistance for downy mildew. As in Brazil, anthracnose is a major disease problem here also. The third ranking disease is sugarcane mosaic virus which is not important in Asia and Africa. Plants showing symptoms to these diseases plus zonate leaf spot were easily observed in the field that we saw; downy mildew and sugarcane mosaic virus were the most serious in the field. Breeding for resistance to these diseases would be an important aspect of an ICRISAT program in the Americas. Cooperation with the ICRISAT Center and other regional locations would be beneficial for all but sugarcane mosaic virus which must be done locally.

The two insect pests of importance are the fall army worm and the midge. The fall army worm begins feeding on the plant from the early seedling stage on. The insect can be controlled by spray or granules. However, pronounced differences in varietal susceptibility have been observed but no breeding effort to utilize this has been undertaken. Midge is a sometime problem but it would be worthwhile incorporating existing levels of tolerance into adapted useful material. Breeding for resistance to these insects seems promising and beneficial and could easily be part of an ICRISAT regional center in the Americas.

Dr. Riccelli is a knowledgeable man who could tell us much

Guatemala, October 1 to October 3:

Research in Guatemala is undertaken in the organization "Instituto de Ciencia Agricolas" (ICTA). ICTA developed from a reorganization of the Agricultural Sector, the movement beginning in 1970. There were two principal goals: increased food production, especially of the basic grains (which includes sorghum), and to stimulate rural development. The responsibilities of ICTA can be interpreted as follows: ICTA has a direct responsibility for creating, identifying, generating technology, testing it under conditions where it will be used, and adapting it to these same conditions. ICTA has further decided that it must know the results of the technology when in the hands of farmers.

Within ICTA, Dr. Albert N. Plant is Coordinator for the sorghum program.

Guatemala is a country of many agro-ecological situations. There is a broad coastal plain, varying up to 40 miles in width along the Pacific coast of the country. Rainfall in this region is approximately 1000 mm. The rainfall across the country decreases from the border with Mexico to the border with El Salvador. Mountains rise steeply from this coastal plain and rainfall can be very high 4000 to 5000 mm. Behind the mountains the rainfall drops, usually between 1000 and 2000 mm.but falls as low as 500 mm. The north western part of the country is considerably less mountainous, more sparsely populated and not in an area where sorghum is of concern. Soils are generally acid with pH of 6; some soils in very high rainfall areas are more acidic. The soil has adequate potassium but requires nitrogen and phosphate.

The major sorghum production takes place on large farms along the Pacific coast and in the mountain areas of Jutiapa, a provincial area in the Eastern part of the country bordering El salvador. Possible expansion to the west (Chimal tenango) and to the north (El Oasis) provincial areas is a possibility. Sorghum was produced on some 36,000 hectares in 1971-72 with a production of some 822,891 quintals of grain. This comapres with a production of 16.2 million quintals of maize, 1.4 million quintals of beans, 1.3 million quintals of rice, and 4 million quintals of wheat.

The sorghum produced on the coastal plain comes primarily from commercial hybrid seed companies, Dekalb, Pioneer, Northrup King and Asgrow. Pioneer and Dekalb have programs in Nicaragua where they evaluate varietal materials from their programs in the USA and Mexico. There are some problems: seed parents from the USA are poorly adapted so yields in production fields if local production were attempted would be poor, it appears that locally developed hybrids will out yield those from US companies, and the grain from these hybrids is useful only for animal feed.

The bulk of the food grain of the country is produced by the campesino or peasant on small farms in hilly mountainous areas. This is a traditional type sorghum, growing to 3 or 4 meters in height with white grain that is wet milled after soaking in alkali and made into tortias. About 60 percent of the sorghum produced in this way goes into human food. The hybrids from seed companies do not serve this area at all, they are unadapted and of non-food type grain quality. Locally developed varieties and hybrids for such areas are in the research stage.

Rainfall in the sorghum area varies from 1000 to 2000 mm. and falls from May to mid-October early November. There is a pronounced bi-modal pattern with little or no rain in August. Inspite of this high rainfall sorghum is grown because of drought conditions. The drought conditions arise because of the high variability in rainfall pattern and because of steep slopes, poor water penetration and thin soil layers with poor water holding capacity. Much of the cropping in these regions in Central America is more or less as follows: Corn, sorghum and beans are all sown in May. Sorghum maybe sown in the same row as corn or between rows of corn. Beans are frequently inter sown between rows of corn. The corn grows faster than the sorghum which is held back during the first rainy period. The corn matures by late August early September and is broken over just below the ear. The sorghum has a more favourable environment and grows through the corn flowering in mid-November. This year early rains were bad, the corn looked poor and sorghum will be the productive crop.

It seems that a contribution could be made if some 30 to 45 days were removed in the time to flower. With rains stopping in mid-October to November moisture frequently become limiting on these droughty soils and yield is reduced. Also, the grain-straw ratio is about 1 to 5 indicating that there is a lot of dry matter production but mostly in leaves and stems. A change in plant type would likely result in higher yields. This is a difficult situation to work for, the materials developed in the USA and for many of the drier shorter season areas do not fit. Less work has been done to develop suitable types for the long growing season. ICRISAT, with its opportunities in Africa should be able to help develop such materials.

There are other possibilities in the cropping sequence, sow sorghum in May, harvest in August and ratoon harvesting again in November. Corn might be sown in May, harvested in August and sorghum sown in August to be harvested in November. The rainfall in the August period is very uncertain making sowing at that time risky. The opinion was expressed that it will likely not be possible to move away from combined sowing of corn and sorghum in May. The 3 local varietal types generally sown in May are: Cacko de Chivo, Paquete and Sapo. We had the opportunity of seeing one or more of these during a trip into 3 valleys in the Jutiapa area, the Jutiapa Valley, Asunsion Mita Valley and the Jalpatagua Valley (all 500-650 meters in elevation). These valleys take their names from towns in the valley. The speculation is that these local varieties came from Ethiopia but no one is sure. We were ahead of flowering so did not have a chance to see but a few heads. The crops were badly mixed in seed type and generally very ununiform in development. Most of the sorghum of this type is sown in an elevation ranging from 800 to 1200 meters.

The research program of Dr. Plant is directed toward the development of varieties and hybrids flowering in about 60 days. He has close contact with Texas A&M and obtains much of his material form them. His program is fairly extensive, directed toward the large mechanized production units on the coastal plain and to try to ratoon and to undertake August sowings in the more hilly areas. He is working for a good grain quality type. He has had trouble finding good A-lines for hybrid seed production but is satisfied with a 7501 to 7505 series of A&B lines from Fred Miller. Some of his best hybrids have been with 7503 as seed parent and yield at the coastal Cuyuta Experiment Station have ranged from 4 to 9 tons of grain per hectare. He estimates his yield advantage from hybrids at about 40% greater than the varieties. He concurs in the need to identify better A-lines and feels that ICRISAT could contribute.

He feels that the long season sorghums used in the hilly areas should be reduced in duration but he did not indicate any activity that he is undertaking to achieve this.

Anthracnose in the head was mentioned as the number one yield limiting factor. Anthracnose on the leaves and stem apparently is much less severe. It is apparently severe about once in four years. There is some confusion on the race situation of anthracnose. It has now been indicated as severe in Brqzil, Venezuela and Guatemala. Varietal reaction to anthracnose in Guatemala appears to be similar to that in the USA, however, reactions in Venezuela and Brazil are reported to differ. This racial difference, if real, would be important to a crop improvement program. One is also impressed by the wide spread severity of this disease. Although present in India and Africa it is generally not so important. Resistance to anthracnose could be undertaken as part of a research program of an ICRISAT Center in the Americas.

Downy mildew was also mentioned as a problem. It has entered Guatemala from Mexico and is slowly moving in the country. Apparently it is also present in El Salvador and has come into Guatemala from there. At present the severity is low and the disease is almost not found in the coastal area. There is fear of its spread and it was felt that in the not too distant future quarantine may require that seeds that move internationally in the region come from fields certified to be free of this disease. There is a greater fear of downy mildew on corn because it can be more devastating and more difficult to realize resistance through breeding.

Coffee rust has occurred in Nicaragua and apparently affects sorghum. Sorghum from Nicaragua is not permitted entry into Guatemala for this reason. This is affecting the market operation of Dekalb and Pioneer who produce and market seed from Nicaragua. This would also be a consideration for ICRISAT in locating a regional center.

Maize dwarf mosaic virus is seen on occasion and is not a problem.

The major insect pest is the midge. This insect entered Guatemala a few years ago from Mexico and has just about entered the sorghum area adjacent to the El Salvador border. Breeding for resistance to this insect is an important part of the program of Dr. Plant. He is using the sources of resistance from Texas with good success. In fields where normals are 40-60% infested, his recovered types using the Texas source are only about 10% infested.

The fall army worm and the sugarcane borer were mentioned as pests but easily controlled by insecticides if they become serious (which was not often).

We observed a low level of leaf feeding on the trip that we made. We saw very few diseases and commented frequently how free of disease the plants were. Apparently the local types have a higher level of resistance than the introduced hybrids and some diseases symptoms are more apparent later in the life of the plant. Nitrogen deficiency was frequently observed and at times phosphate.

There is a regional yield testing program in Central America for several crops including sorghum. These trials are organized by the PCCMCA, an organization among the plant breeding group. Each year a new president and secretary are elected and they are responsible for organizing the trials and making the final report. They also call an annual workshop meeting of about 5 days duration. Entries for the next year are decided at this meeting. Dr. Plant felt this function valuable but ineffective. Seeds do not arrive on time, data is not returned and a report is written about 30% of the time. This is a Central American

function not including South America. Through an ICRISAT regional center, possibly more organization could be evolved. The regional center could service the PCCMCA sorghum program and use this as a vehicle for regional evaluation. It could help expand this program to include disease and insect nurseries if this would be desirable (some such nurseries are currently being distributed by Texas A&M but this might somehow be rationalized via Title 12 - ICRISAT cooperation).

Guatemala is close to Mexico and Dr. Plant was quite warm in extending an invitation for cooperation with Vartan. It would be valuable for Vartan to travel some in Guatemala with Dr. Plant to gain greater appreciation of sorghum, its uses and problems. Dr. Plant offered land facilities for screening elite germplasm as well as to evaluate special traits such as tolerance to grain mould, anthracnose, etc. There is interest in evaluating cold tolerance material from CIMMYT in Guatemala but not at extremely high elevations, likely no higher than 2000 meters. Some of the material now in the cold tolerant program might suit these slightly lower elevations where the season is longer and the maturities now available in the cold tolerant program will fit. There has been a substantial introduction of varieties, many from Ethiopia, in the cold tolerance program. Segregates from crosses will have a range of maturities. It seems a shame to discard later maturing types when these might be very useful in the 400-1200 meter altitude range where there is currently so little new sorghum types to try and where most of the sorghum in Central America is grown.

CIMMYT, Mexico, October 3-6:

The purpose of this visit was to help Vartan Guiragossian begin his assignment as the ICRISAT sorghum breeder stationed at CIMMYT. Arrangements for his stay were made, he met many people of the CIMMYT staff, and had a good look at the University at Chapingo and at INIA. Leopoldo Mendoza is a physiologist stationed in the genetics department working on sorghum. The director of the INIA station adjacent to the Chapingo Campus is Dr. Aquiles Carballo. He was joined by two colleagues, Victor Gonzales who concentrates on corn, and Immanuel Livera, the sorghum breeder, in showing us their rather extensive sorghum program. A base for cooperation with these agencies was established. These people will also help orient Vartan to sorghum in Mexico. Within CIMMYT, Vartan will be closely associated with maize program.

Vartan will have access to the four locations with CIMMYT but the most important to him will be El-Batan (2200 m) Tlitizipan (950 m) and Poza Rico at (50 m). Poza Rica will be useful for off-season activities and for disease evaluation during the main season. Tlitizipan will provide for an intermediate elevation and is more typical of most of the sorghum growing regions in the Americas. Efforts to develop cold tolerant

types can best be done at El-Batan. Vartan has been offered a total of ten hectares per year for all seasons and locations. However, he can spill over on to land of the University at Chapingo.

We looked primarily at sorghum, being developed for cold tolerance to be grown at elevations above 2000 meters and in rainfall areas ranging from 500 to 650 mm. About 20% of the area in this climatic region is irrigated. To complete a life cycle in this environment the crop should mature in 90 to 110 days. The very best entries require 75 to 85 days to flower and 115 days or more to mature. Flowering of 90 days is not unusual in entrries tolerant to the cold (will set seed) and for new materials being developed flowering frequently requires 120 days or more. Obviously, theneed to realize earlier maturing types in this climatic situation is of top priority for the breeding program. There are a few lines with INIA that they feel can be released for farmer use in areas where there is irrigation and night temperatures do not drop below 5$^{o}$C (flowering in about 80 days).

The source of cold tolerance came originally from 3 lines from the Ethiopian-Ugandan area. Almost all of the useful selections have coloured grain, many bitter. There is a demand for animal feed and sorghum produced in high elevation areas is needed. However, there is a recognized need for sorghum for food but there is little effort outside of the program at CIMMYT to develop such grain. This is clearly an opportunity for ICRISAT. The same is true for sorghums for lower elevations.

The program at CIMMYT is making an effort to diversify the variability available. Many sources from Africa are being used. Some of these have cold tolerance, all are late, but there are many possibilities to select useful entries for lower elevation areas. This effort to diversify the germplasm will be useful to many breeding programs in the Americas including those at high elevations. This is a valuable function for ICRISAT to continue.

There is concurrence to develop hybrids, particularly A-lines that are adapted to tropical areas and to work on the disease problem, particularly anthracnose.

APPENDIX III

# COMPARATIVE CASES OF VERTICALLY INTEGRATED AGROINDUSTRY: MEXICO VENEZUELA, COLOMBIA, PERU, ARGENTINA

Alexander Grobman, Ph.D (1)

(To be presented at the "Nutrition and Agricultural: Strategies for Latin America" Symposium. Interciencia/American Association for the Advancement of Science. February 13-14, 1978, Washington, D.C.)

Agricultural research in Latin America has produced notable results in various crops in terms of increased production and yields in several countries. Well documented cases for Wheat and Maize in Mexico (1), Cotton in Brazil (2), Maize in Peru (3), Rice in Colombia (4), Rice, Soybeans, Wheat, and Cotton in Colombia (5), have been presented and analyzed (6).

Momentous increases in production of sorghum, and soybeans have ocurred in Latin America in the past 15 years. They are intimately linked to an extraordinary development of the poultry and feed industries in many countries over the same period of time.

Considering the protein deficit in the diets of a significantly large proportion of the population of most countries of Latin America, the impact of the increase of supply of poultry products, and the cropping patterns, and industrial integration that lead to it acquire very great importance.

Very unique circumstances, and very specific technologies,were blended together in a complementary manner, to bring about the results which will be discussed below. A selection of the five larger Latin American countries, with the exclusion of Brazil, was made, in order to document with a case study the nature of the vertical integration of seed, feed, and poultry industries in Argentina, Colombia, Mexico, Peru and Venezuela. In all of these countries parallel developments took place. While in Argentina the opportunities derived from an expansion in production lead directly towards export, in the others the increased grain output was mostly directed to their internal market.

In Brazil, such a large role is played by area expansion in explaining the increase of output, that derivation of conclusions from

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the Brazilian model would not have application to the other countries. The fact that sorghum did not have any significant development in Brazil is due to the overwhelming expansion of soybeans, requiring less fertilizer than sorghum, and to promotional policy of the country towards expansion of soybeans exports. Brazil had earlier taken vigorous steps to increase beef production through support of ranchers (about 2,000 units) operating at high entrepreneurial levels of efficiency. Poultry production, thus had a low priority in governmental support policies in Brazil.

The selection of the poultry - feed - veterinary drug supply-seed complementary activities in the countries mentioned for a case study of industry integration was made with a rationale. The appearance of technologies which were complementary, which were first brought by multinational corporations, that were easily transferable, and of wide adaptation (low technology x site interaction), made for quick step-wise adoption in the various countries.

There are other, smaller countries especially in Central America where an adoption process of the seed-feed-poultry technologies has been also very successful.

## CROP PRODUCTION TECHNOLOGY

The tremendous increase in feed grain production that in most cases served as a base for the increase in production of poultry products was spearheaded by sorghum in the sample of countries selected. In Peru, maize was of extreme importance, as was also the very great increase in anchovy catches off its coast that reached 10,000,000 tons annually in the early 70's, and which was transformed into fish meal, a basic ingredient of poultry rations in most Latin American countries in the early 70's. The production of soybeanas really acquired momentous growth from the time when anchovy catches off the Coast of Peru slipped back, due to the disappearance of the anchovy because of unfavourable ocean temperatures for anchovy breeding and overfishing from 1973 onward.

Crop production technologies, based on hybrid sorghum, hybrid maize, use and availability of fertilizers, tractor power, herbicides, combines, and the introduction of high yielding soybean cultivars, lodging-resistant, shatterless, and combinable were the bases on which a profitable agricultural pattern emerged.

Very little of this technology went to small farmers. It was intended to either by the technology generators and promoters or by the governments. In Mexico, the sorghum areas were mostly located in previously large cotton estates; rice was also expelled from the new sorghum areas. These were mostly medium to large farmer crops. In the sorghum areas of Venezuela, Argentina and Colombia there were also large

farmers. In Peru, larger farmers started planting sorghum, and as the Agrarian Reform proceeded, large agricultural units were retained in the process, so that no real change in economies of scale occurred, as large units continued planting hybrid corn and hybrid yellow feed sorghum.

In all of these countries the emphasis was set in quick-high technology increase in grain production, over the shortest time span. This was achieved very quickly and efficiently, very little extension outlay having been needed in the process. The technologies were to a great extent transferred in complete packages and very easily adopted and adapted by farmers, who counted with a basically unlimited market, and prices mostly above international standards.

SORGHUM

Sorghum, a cereal originated in Africa, and brought to the American continent initially with African slaves in the Colonial periods, did not really become important in the Americas until very recently. Only in the Southern Wheat Belt of the U.S. (Kansas, Oklahoma, and Texas) large sorghum acreages were grown during the last years of the XIXth Century. It became excellently adapted to this semi-droughty area. Varieties selected for earliness, photoperiodic insensitivity, short height, and with resistance to several diseases, including anthracnose, charcoal rot, head smut, and milo disease were developed in the early years of this century.

Some sugary strains used both for forage, and for making syrup appeared, and were popular for many years (Sugar-Drip, Atlas, Leoti).

As combines became more pervasive throughout the southern wheat belt, varieties were bred for mechanical harvesting. Use was made of the dwarfing factor attached to a series of four genes (dw, $dw_2$, $dw_3$ and $dw_4$), and of four maturity genes (ma, $ma_2$, $ma_3$, and $ma_4$), in order to create 3-dwarf of 4-dwarf homozygous varieties with earliness and photoperiod insensitivity.

These modern varieties were available in the 40's and 50's. Some introductions took place into Mexico and South America, but only Argentina grew some significant areas.

While Dr. Arthur Swanson introduced under his Point-Four Program some dwarf sorghum varieties that performed well in experimental plots and demonstration fields in the early 50 s in Peru, they were not adopted commercially in that country, at all.

Some tall, rather late sorghum varieties, with while endosperm had been grown in Central America for many years, and used as sources of flour, which when mixed with flour from white maize varieties was used in tortilla making. This type of sorghum whose origin is lost in history

is usually planted in missing corn hills in several Central American countries, especially Nicaragua, Honduras, El Salvador, and Guatemala. Small areas of "milo" may be milo sorghum were also traditionally planted on the Atlantic coast of Colombia, and in Western Venezuela.

All these small traditional areas of sorghum were of no real importance, as compared to the large increases in areas that took place in the nineteen sixties.

The breakthrough was brought about by the discovery in 1956 by Stephens (6) in Texas of a sorghum plant with cytoplasmic and male sterility. The existence of heterosis or hybrid vigor in sorghum crosses had been already demonstrated. The discovery of a feasible mechanism for producing $F_1$ hybrid seed in a commercial scale by using a male-sterile parent, cytoplasmically sterilized, and a gene-restorer male parent, formed the basis of a strong hybrid sorghum seed business in the U.S. Hybrid maize seed companies, with experience in production and marketing of maize hybrid seed undertook the activity of production and marketing of hybrid sorghum seed. Some companies with no previous experience in hybrid corn seed production participated also in this market.

By 1959-60 hybrid sorghum seed production was well in its way as a solid industry in the U.S. and trials in Mexico, Argentina, Australia, and South Africa, had proven an amazing fact: U.S. bred sorghum hybrids performed in all those countries exactly as they did in the U.S. While hybrid maize exhibited a high location x genotype interaction in yield, hybrid sorghum did not. This very important fact was quickly realized by U.S. seed companies, and their early establishment in 1960 in Argentina, and Mexico, countries with large, semi-dry areas, assured the further development of sorghum as a crop in those countries. The adaptation of U.S. hybrid sorghum to many other countries not only in the subtropical, but tropical areas, as well, was later confirmed.

U.S. bred sorghum hybrids, adapted to combine harvesting found their place very quickly in the cropping patterns of medium and large farmers. In Mexico, sorghum was quickly introduced in the irrigated valleys of the Northwest, in the La Laguna area near Torreon, previously a cotton area, in the cotton lands of Tamaulipas, and in El Bajio - the intermediate alititudes of Central Mexico. Very quickly, Mexican farmers borrowing U.S. production technology, learned by driving across the border, and watching, and talking to U.S. farmers, were obtaining yields equal or higher than in the U.S.

As sorghum production soared in Mexico, the authorities in control of irrigation water in the irrigation districts, realized the great efficiency of sorghum in terms of use of irrigation water. About 1 Kg of sorghum grain may be obtained from 1 cu meter of irrigation water, twice as efficient as cotton, and four times as efficient as rice.

Because sorghum could use the same planting and harvesting machinery as wheat, a rotation sequence of wheat-sorghum became firmly established in the Northwest, permitting a rational use of water, land over two seasons per year, and the amortization of agricultural equipment over two crops per year.

Credit, and the allocation of irrigation water by the Mexican authorities was the local contribution. A transferable technology of hybrid seeds, and the setting up of mechanisms for seed production, distribution, and for demonstration of production technology was due to U.S. seed companies. While prior to 1950, Mexico produced less than 200,000 tons of sorghum, in 1965, production had gone up to nearly 750,000 tons, in 1970 to 2½ million tons and in 1976 to 3.35 million tons. The magnitude of the sorghum production in Mexico has exceeded that of wheat (7) in rate of growth as well as total production.

It is also interesting to note that the yield of sorghum was nationally 2,839 kilos/ha in 1976, as compared to 1,278 kilos/ha for corn the same year, and this in spite of corn research in Mexico for over 30 years.

Sorghum production in Mexico went basically to the feed mills, for production of poultry, hog, and dairy cow balanced feeds, releasing millions of tons of corn from this use, for the direct human consumption by the expanding population of Mexico (7)

In short, from 1961 to 1976, sorghum area in Mexico expanded 1000%, and production 1,150%. Yields increased 14% in the same period.

In the meantime, in Argentina, a process similar to that in Mexico was taking place. Earlier sorghum varieties adapted to combine harvesting were being planted in the dryer areas of the province of Buenos Aires, in La Pampa, Cordoba, and Santa Fe. Some of these varieties had been improved at the Pergamino Station, from U.S. introductions. When in 1960, over 700,000 has. were planted to sorghum, already some hybrid seed, mostly produced by local licensees of 4 U.S. seed companies was already in use. By 1969 the area planted in sorghum was 300% that in 1960, and production had increased 400%; by 1974 the area planted had increased 400%, and production 950% over that of 1960 (Table A-1).

As sorghum moved into the dryer areas of the Argentinian Corn Belt, an interesting phenomenon took place with maize. Because maize was left in the more humid areas of the province of Buenos Aires, maize yields went up (1,700 Kg/ha in 1960 to 2,840 Kg/ha in 1974.) Again in spite of sorghum being an imported technology, sorghum yields, as an average, are similar to the yields of maize in Argentina, in spite of the distribution of both crops in different precipitation areas (mean sorghum yields 1973-76 are 2529 Kg/ha, while mean maize

yields 1973-76 are 2546 Kg/ha).

The big push in sorghum acreage in 1967 and later years came about through decision of the seed companies, in some case to treble their sorghum seed production, from one year to the next, and then to apply energetic sales pressures by elaborative incentives to seed salesmen, and also very importantly to their wives.

The role of the CREAS, organizations made up of 6 to 8 farmers each, which hired their own technical assistance agents, was very important in Argentina in the acceptance of the new sorghum technology. An opportunistic approach of one of the seed companies, in producing a double - purpose sorghum hybrid for both grain and grazing (NK-300), allowed this single hybrid to capture and hold fully 25% of the sorghum area of Argentina. When grain price fell, cattle were driven into the sorghum fields to graze plants in the milk to dough stage.

As in Mexico, in Argentina, continuous research by the seed companies improved their products in terms of yield, disease resistance (especially to downy mildew) and more specific to finer adaptability.

The increased sorghum production of Argentina went into export channels. While in 1960, Argentina exported 58,434 tons of sorghum, in 1974 sorghum exports attained 3,058,545 tons (of which 1.8 million tons went to Japan) (Table A-13). It is expected that with the policy of the Argentinian Government since 1976 of returning to farmers a higher percentage of export duty retention, in fact increasing farmers receipts, a strong incentive to increased sorghum production will be present. This is already noticeable in earlier reports of the 1977 grain crops. In Table A-7 it may be seen that sorghum prices to farmers in Argentina had been lower than international market prices, and lower than those in the other Latin American countries. Even so, because of low production costs ( no fertilizer use), sorghum production in Argentina remained efficient.

In Colombia, sorghum cultivation acquired momentum since 1966 when 30,000 has were planted, with a production of 60,000 tons. By 1976, 173,600 has were being planted annually, with 427,000 tons production, which means an increase in area of 578%, and an increase in production of 713%.

The earliest instance of sorghum promotion in Colombia came from an international feed production company. I had made an agreement with a U.S. seed company, and acted first as importer, and later as licensee of sorghum seed production in Colombia. Another competing feed mill, previously integrated with poultry production entered into an agreement with a competing seed company. Two other local seed companies obtained license agreements from respective U.S. seed companies.

By 1975 sorghum seed production was fully desintegrated from feed production, and established as an independent business.

The growth of sorghum in Colombia, even though promoted by both seed and feed companies, went through vagaries of incentivation and desincentivation by feed companies and by the government price support and grain import institute, IDEMA. The feed companies were more motivated by short term gains in playing the market, and lowering prices in times of abudance, than on stabilizing market prices and internal supplies. They knew that they could always fall back on IDEMA for low cost grain supplies imported from the U.S. IDEMA obliged with such poor timing that it managed to import maize (once on 83,000 ton importation in 1971 at sorghum harvest time, another time in 1976), precisely in time to depress sorghum prices, and discourage farmers from expanding sorghum areas.

Sorghum areas in Colombia are found in the Tolima (upper Magdalena Valley), where cotton was displaced, on the Atlantic coast, in rotation with cotton, in parts of the Central Cauca Valley, and in the Llanos (oriental savannas, near the city of Villavicencio).

Introduction of cultivars, and selection in Colombia, has resulted in public cultivar, and a private one (non-hybrid), which are extensively grown, next to U.S. hybrids in Colombia.

The introduction of sorghum hybrids in Peru was made in 1963 by SIPA (a research - extension - promotion branch of the Minstry of Agriculture). By 1965 three hybrids had been identified and some 90 farmers had planted observation plots of 1-5 has each from imported seed.

One seed company undertook importation first, and production later of commercial hybrid seed in Peru. Seed was sold for planting in minimum lots of 100 has, in order to avoid bird damage. If areas smaller than this were available, in individual farmers fields, they were encouraged to aggregate adjoinning areas, in order to beat the bird problem. Three large feed millers were asked to produce buying guarantees in each season for sorghum grain at a price 85% that of corn, such prices being fixed together with corn prices for each calendar year. These guarantees produced the momentum needed to introduce the crop. Prices later went up and stayed at 90% the price of commercial yellow corn till this date.

Field demonstrations, and meetings with farmers, were used to transfer a technology based on the use of 5 to 6,000 cu meters of irrigation water, 150 kilos of N fertilizer, and 17 kilos of seed, all per hectare. yields immediately shot up, and stayed up at the highest levels in Latin America (3,269 kilos/ha).

Net returns for sorghum were about 80 to 100% on the crop investment (direct plus indirect costs considered).

If in 1974 about 1,50 Soles/cubic mt. of water was a mean return for sorghum, similarly for cotton it would have been 0,75 Soles, for rice 0,50 Soles, and for sugar cane about 1,20 Soles. It is lower, relatively, now for sugar cane on account of lower sugar prices.

The attractiveness of sorghum, in addition to the ease, of cropping, sure market with assured prices, low irrigation water requirement, and quickness for the crop (100-120 days), is its low requirement of cash investment (about 100 to 150 dollars/hectare) requirements.

The sorghum areas of Peru are concentrated in the large irrigated valleys of the northern coast (Piura, Lambayeque, La Libertad) and in the southern coastal valleys (Ica, Chincha, and Pisco).

In Venezuela, the same feed company that introduced sorghum in Colombia was also active in the early days. Two seed companies participated also with testing commercial, and experimental sorghum hybrids. Sorghum production technology tested and validated in Venezuela was available as early as 1968, when sorghum production reached 22,000 tons. In succeeding years, sorghum production was discouraged by the feed mills, who became involved in large scale feed wheat (low-grade wheat), maize, and sorghum imports (Table A-12). Maize and sorghum imports combined had reached 760,000 tons by 1973 and 940,000 tons by 1974. At this point, and with the advent of new government, that stressed the national objective of expanding Venezuela's agricultural output, investing in it the recently earned oil revenues, feed millers went back into promoting once more the production of sorghum, under the assurance that import licenses were no longer guaranteed for feed grains, and that the imports, at any rate would be effected by a public entity, the Corporacion de Mercadeo. After having been convinced by seed producers of the need for better farmer prices, the Association of Feed Producers asked for, and obtained higher control level of prices for feed poultry meat, and eggs. Only then, a nation wide campaign with farm leaders, and farmers organization was possible. Joint field promotional action of seed and feed company agronomists took place.

The Venezuelan Government made production credit easily available. Seed was imported every year from the U.S. (less than 10% was produced locally).

By 1976 the area had gone up to 145,000 hectares, and it is expected that the 1977 area exceeded 300,000 hectares. Production went up to 238,000 tons, and imports dropped to 610,000 tons of combined corn and sorghum in 1976. Increased production was 2,160% from 1966 to 1976. Sorghum growing areas are concentrated in the Barinas - Guanare - Acarigua area of the Western Llanos, in the Central Llanos, and around Maturin in the Eastern Llanos.

Research in the development of sorghum hybrids was started by a local company, which started marketing some hybrid seed in 1976.

Table A-9 MAIZE: Use of Improved Seed, 1970 - 1976

| YEAR | ARGENTINA | | COLOMBIA | | MEXICO | | PERU 1/ | | VENEZUELA | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons | Area % | Tons | Area % | Tons | Area % | Tons | Area % | Tons 3/ | Area % |
| 1970 | 105,000 2/ | 80,0 | 2,836 | 25,4 | 8,928 | 9,0 | 2,050 | 90,0 | 7,177 | 60,0 |
| 1971 | 104,844 2/ | 80,0 | 2,741 | 23,5 | 9,230 | 9,0 | 2,050 | 90,0 | 6,055 | 60,0 |
| 1972 | 70,944 2/ | 80,0 | 3,039 | 31,1 | 8,751 | 9,0 | 1,780 | 90,0 | 5,300 | 60,0 |
| 1973 | 84,071 3/ | 80,0 | 2,847 | 28,5 | 9,127 | 9,0 | 1,710 | 90,0 | 6,500 | 60,0 |
| 1974 | 66,144 est. | 80,0 | 1,928 | 19,2 | 8,060 | 9,0 | 2,400 | 95,0 | 6,500 | 60,0 |
| 1975 | 61,936 est. | 80,0 | 2,455 | 23,6 | 8,031 | 9,0 | 3,200 | 95,0 | 6,343 | 60,0 |
| 1976 | 59,136 est. | 80,0 | 2,590 | 22,2 | 9,480 | 9,0 | 3,500 | 95,0 | 8,500 | 60,0 |

SOURCES: Bolsa de Cereales, Numero Estadistico, 1976, Buenos Aires, Bogota
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. FAO, Production Yearbook, Vols. 24-29, Rome
. Ministerio de Agricultura, Programas Agricolas 1971-1976, Oficina de Planeacion del Sector Agropecuario, CPSA, Bogota - Colombia
. Ministerio de Agricultura, Insumos Agropecuarios 1976, OPSA, Bogota, Colombia
. Ministerio de Alimentacion, Indicadores Socioeconomicos del Sector Alimenticio, OSPA, Direccion de Planes y Programas.

1/ Hard yellow corn
2/ Banco Ganadero Argentino 1973
3/ Memoria de FONAIAP, 1976

Table A-10 SORGHUM: Use of Improved Seed, 1970-1976

| YEAR | ARGENTINA | | COLOMBIA | | MEXICO 2/ | | PERU 3/ | | VENEZUELA | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Tons | Area % | Tons | Area % | Tons | Area % | Tons | Area % | Tons | Area % |
| 1970 | 18,000 | 1/ | 1,019 | 98,4 | 14,250 | 79,0 | 79,0 | | 51,0 | |
| 1971 | 35,318 | 1/ | 1,702 | 100,0 | 12,300 | | 165,0 | | 34,0 | |
| 1972 | 19,374 | 1/ | 1,837 | 100,0 | 15,945 | | 160,0 | | 85,0 | |
| 1973 | 21,945 | 1/ | 4,418 | 100,0 | 17,775 | | 162,0 | | 102,0 | |
| 1974 | 31,140 | est. | 3,004 | 100,0 | 17,295 | | 166,0 | | 480,0 | |
| 1975 | 26,010 | est. | 4,112 | 100,0 | 16,740 | | 245,0 | | 790,0 | |
| 1976 | 23,573 | est. | 4,209 | 100,0 | 17,700 | | 343,0 | | 2.045,0 | |
| 1977 | | | | | | | 460,0 | | | |

1/ Banco Ganadero Argentino 1973
2/ Estimate
3/ Hortus S.A. Report 1978

**Table A-23 AVERAGE POPULATION AND ANNUAL GROWTH RATES, 1966-76 (PERCENTAGE - 1.000 RESIDENTS)**

| YEAR | ARGENTINA 1.000 Inhabitant | Growth Rates | MEXICO | | COLOMBIA | | PERU | | VENEZUELA | A |
|---|---|---|---|---|---|---|---|---|---|---|
| 1966 | 22.770 | 1.32 | 44.200 | 3.39 | 19.270 | 2.18 | 11.970 | 1.84 | 9.486 | 3.94 |
| 1967 | 22.800 | 1.36 | 45.700 | 3.50 | 19.690 | 2.84 | 12.190 | 3.04 | 9.860 | 3.35 |
| 1968 | 23.110 | 1.38 | 47.300 | 3.51 | 20.250 | 2.86 | 12.560 | 2.98 | 10.190 | 3.24 |
| 1969 | 23.430 | 1.37 | 48.960 | 3.53 | 20.830 | 2.74 | 12.930 | 3.09 | 10.520 | 3.33 |
| 1970 | 23.750 | 1.35 | 50.690 | 3.47 | 21.400 | 2.66 | 13.330 | 3.08 | 10.870 | 3.40 |
| 1971 | 24.070 | 1.33 | 52.450 | 3.47 | 21.970 | 2.46 | 13.740 | 2.98 | 11.240 | 3.11 |
| 1972 | 24.390 | 1.35 | 54.270 | 3.48 | 22.510 | 2.31 | 14.150 | 3.04 | 11.590 | 3.11 |
| 1973 | 24.720 | 1.33 | 56.160 | 3.49 | 23.030 | 2.26 | 14.580 | 3.09 | 11.950 | 3.10 |
| 1974 | 25.050 | 1.32 | 58.120 | 3.49 | 23.550 | 2.29 | 15.030 | 3.06 | 12.320 | 3.08 |
| 1975 | 25.380 | 1.30 | 60.150 | 3.49 | 24.090 | 2.28 | 15.490 | 2.97 | 12.700 | 3.07 |
| 1976 | 25.710 | | 62.250 | | 24.640 | | 15.950 | | 13.090 | |

SOURCES: USDA - ERS, Indices of Agricultural Production for the Western Hemisphere excluding the United States and Cuba, 1966 through 1976 and 1967 through 1977. Statistical Bulletin 552 and 569, Washington, D.C. May 1976 and 1977.

Table A-22 AVAILABILITY OF FOODSTUFFS IN 1974: GRAMS OF PROTEIN PER PERSON / DAY

| SOURCE | ARGENTINA | COLOMBIA | MEXICO | PERU | VENEZUELA |
|---|---|---|---|---|---|
| Total | 107.1 | 47.0 | 66.9 | 61.7 | 63.1 |
| Vegetable Products | 40.2 | 25.9 | 47.9 | 39.7 | 32.4 |
| Animal Products | 66.9 | 21.2 | 19.0 | 21.9 | 30.8 |
| Meat and Edible by Products | 48.6 | 8.2 | 8.6 | 9.8 | 16.7 |
| Eggs | 2.0 | 1.3 | 1.8 | 0.7 | 1.8 |
| Fish | 2.1 | 1.3 | 1.6 | 4.5 | 3.1 |
| Milk and Milk Products | 14.1 | 10.3 | 6.9 | 6.9 | 9.1 |

SOURCES: Monthly Bulletin of Agricultural Economics and Statistics. Vol. 25, No.4,1976

# "CERRADO": REGION OF HIGH AGRICULTURAL POTENTIAL AND REQUIRING NITROGEN*

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There are around 183 million hectares under the vegetation called "cerrado", in Brasil, from the Northern Territory of Amapa, as South as the State of Sao Paulo. Its main part is in the Central part of the country in the States of Minas Gerais, Goias, Mato Grosso and the Federal District, where Brasilia is located (Ferri, 76).

This huge region is being utilized in an extensive system of cattle production, with the exception of relatively small areas where an intensive agriculture is practiced with accomplishment equivalent to the agriculture in the traditional areas in original fertile soils.

Among the difficulties for efficient utilization of the "cerrados", are its low soil fertility and its small holding capacity of potash and nitrogen. This probably will make the potash and nitrogen applications rather frequent.

Under this circumstance, the atmospheric nitrogen fixation will be very important. The abundance of legumes among the "cerrado" native supports the hypothesis that Rhizobium is well adapted to "cerrado" soil conditions in spite of its low pH and aluminium toxicity.

The nitrogen fixation through the Spirillum spp. was verified in wheat and corn in "cerrado" soils (EMBRAPA, 76) and there is a hope that it may play an important role in nitrogen supply.

Since the nitrogen is the most expensive nutrient and has to be brought to the "cerrado" region, the atmospheric nitrogen fixation would be an important factor to reduce costs of agricultural production.

The "cerrado" designates four different types of vegetation: (1) grassland, (2) grassland with small trees, (3) the typical "cerrado" vegetation with a lot of small trees and (4) a vegetation with large trees but smaller and different from forest trees. Under the "cerrado" vegetation the soils are different types, but they have a common characteristics:

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they are very low in plant nutrients, mainly in phosphorus, nitrogen, potash, calcium, magnesium, and in several cases in micronutrients as zinc; besides, they are acid, with low pH and in many cases with aluminium toxicity, not because of the presence of large amounts of aluminium but because of the low amount of basis, resulting in a high degree of aluminium saturation.

The low utilization of the "cerrado" region for farming is due to the need of fertilizer application, soil acidity correction and the location in the central part of the country.

Brazil, due to its large area, traditionally developed the agriculture production in natural fertile soils because of the high costs of fertilizers, in relation to the agriculture production due to: a) fertilizer importation; b) high cost of the transportation, distribution and commercialization. Besides, the low value of the land, in relation to the cost of fertilizers, made a better option to use more land than fertilizers, which results in larger profits in a long run, because of the increasing value of the land.

Today, the overall situation is different. Most of the fertile soils are already in agriculture, many for so long, that they are in need of increasing amounts of fertilizers and soil acidity correction. Consequently, the price of land is very high.

The increasing and very fast agricultural expansion, caused by an economic policy of developing the agricultural production, made the prices of land more elevated and gave origin to facilities for the occupation of new land in advantageous conditions.

Also, the migration of the rural population to the cities, better standard of living and social securities, made the labour expensive. In the past, it was abundant and cheap.

The mechanization in the agricultural traditional areas is not so easy in many regions because the majority of the fertile soils are in rough lands. The traditional agriculture also developed more in a non-highly mechanized farming system, due to the fact that the soils were originally covered by forest; clearing it completely was very expensive. The agricultural production of coffee, cotton and many other crops was done by hand or with little mechanization.

The above explains why the "cerrado" region was not utilized before.

For the "cerrado" production a factor is very important: the ratio price of fertilizer and limestone versus the price of agricultural products, at the farms.

The "cerrado" soils are acid and very poor in nutrients. They need a large amount of fertilizers and limestone in the beginning of its utilization, what is the opposite to what happens in fertile soils, which do not need any fertilizer or limestone initially but later, after several years of intensive use.

The unknown possibilities of the "cerrado" region and the high initial investment in fertilizers and limestone, made in the past (and even today), many people doubt of the economic convenience in its utilization.

The Federal Government has under way a program of agricultural research to evaluate the potentials of the "cerrado", to establish the systems of production adequate to the region and to study the basic factors of the agricultural production. Besides, for specific and limited areas it is giving temporary subsidies, and good financing conditions for fertilizers, limestone, clearing of the land, seed bed preparation, and construction of facilities and homes in the farms.

An important point has convinced thousands of farmers of other areas to move to "cerrado": the cost of the land is still so cheap (2 to 20 times less than the fertile and cultivated soils of their own farms), that it is convenient to buy the "cerrado" land because the difference allows to fertilize and add the limestone needed and still one can have larger and better property than the original farm. Besides, he knows that it will not be very long when the "cerrado" land will have a value higher than the price of acquisition.

Summarizing, the "cerrados" were not being used because: (1) abundance of fertile soils elsewhere, (2) high price of fertilizers at farm in relation to the low price of the products in the farm, (3) abundance and low cost of man-power, (4) high price of agricultural farm machinery and its operation in relation to the agricultural products at the farms and (5) last but not less important, the lack of knowledge about the potentials of the "cerrado" territory.

The "cerrados" are being occupied now because of an economical policy to support the agriculture, which has improved the value of the agricultural products of the farms. This gave origin to an agricultural expansion, increased the demands of new lands, increased the prices of the cultivated lands, improved the ratio agricultural products over the input prices, increased the price of man-power and made the farm mechanization more convenient, as a solution to it. The financial policy, with abundant credit made it possible.

The above explanation, although logical, may raise doubts on what will happen. To see what will happen in a future, the best is to

look in the past. Grassland territory of the State of Rio Grande do Sul was very low in plant nutrients and very acid, in the 1950s; today, more than 4 million hectares are cultivated with soybeans and wheat, every year. The same happened with the grassland territory of the State of Parana in the sixties. In the last 5 years, more than 2 million hectares of grassland of the southern part of the State of Mato Grosso, was occupied by farmers and the moving into regions of poor soils but suitable to farm mechanization is increasing every year.

In the future, the still practically untouched "cerrado" areas will be occupied in function of market, price and technology advances.

An estimative of the total potential will be made to give an idea about what it will mean to Brazil and to the world economy.

Considering the "cerrado" area of 183 million hectares (Ferri, 76) and one third of it (55 million hectares) being used for agricultural production (equivalent to the area now used for crop production) it will mean an increase of 162% over 1970 when 34 million hectares were under cultivation (Anuario Estatistico do Brasil, 1975).

The potential of production of those 55 million hectares, if a medium technology and a large area for corn production is considered (a crop well fitted to the overall region), maybe estimated in 165 million tons or 10 times more than today's Brazilian production. Measured as soybean production, whose viability has been proved only in a part of the region but probably will be feasible in all the whole area, the total production would be 82.5 million tons or 7 times larger than the largest Brazilian soybean crop obtained until now.

Considering the world production, those figures for corn will mean 51.2% of the 1975 production and for soybean 120.7%.

Such percentages will never be accomplished in the 55 million hectares considered in that hypothesis because they will not be cultivated with just one crop. However, those figures give an idea on its possibility on grain production, on world basis.

For the world supply it is important to compare the potential and the influence over the international market, the difference between the local production and the local consumption, the surplus to be exported.

Assuming that Brazil is already exporting corn and soybeans, and that the traditional areas of agriculture have still available land and that the yields are still low, it is possible to establish that the traditional area will be able to supply Brazil and that the "cerrado"

production will be exported. The 165 million tons mentioned above are 3.2 times larger than the corn commercialized in the world in 1975 (FAO). The 82.5 million tons of soybeans are 4 times larger than the total soybeans commercialized in the world in 1975 (FAO).

For the above figures, the hypothesis was the utilization of only one third of the "cerrado" for crop production. Let us assume that 15% of the remaining two thirds will not be used. Still, 100.5 million hectares will be available for pasture and forestry. Now, assuming that half of that area will be used for pastures, they will be able to support with technology not advanced (1 head for 3 hectares), more than 25 million heads of cattle. The other half (50 million hectares of forest) also with a medium to low level technology, will yield every year 750 million cubic meters of wood, on the basis of a relative low yield of 15 $m^3$/ha a year.

## Possibilities and difficulties for the intensive use of the "Cerrados"

Because of the heterogeneity of "cerrado" there are so many alternatives that it is not an easy task to evaluate the possibilities and diffficulties, especially if one tries to transform it in money evaluation.

A possible and valid approach was already done by the author (Silva, 76) comparing the factors for production in the "cerrado" and those in areas where the crops are already well established and in economical production, in Brazil.

One of the regions of "cerrado" that, for a long time, have been used for crop production is that of the State of Sao Paulo, called "mogiana" near the region of Triangulo in the State of Minas Gerais. The yield of corn, soybeans, cotton and pastures in the "cerrado" has been the same than that in fertile soils which occurs side by side in the region and had been presenting more facilities to mechanized farming.

Common practice for using "cerrado" is the clearing, planting rice for two years and its transformation in pastures with grasses (Hyparrhenia rufa (Ness) Staff) or Brachiaria sp mainly decumbens and brizanta with a rather low amount of fertilizer (around 30 kg/ha of $P_2O_5$), without any limestone applied. This very simple technology allows an increase of cattle production from 5 ha/1 head to 2 ha/1 head of cattle. This type of utilization of "cerrado" was done already in thousands of hectares in the States of Minas Gerais, Mato Grosso and Goias.

In the "cerrados" of Federal District with the soil conditions described (Brasil, 70) which are considered typical and representative of a very large area (Cline and Buol, 73), with a so called corrective fertilization of 200 kg/ha of $P_2O_5$, besides a partial correction of the acidity (just enough to neutralize the aliminium toxicity, usually 2 to 4 t/ha), the soil fertility reaches a level equivalent to soils in use in the State of Rio Grande do Sul for many years, for soybean

and wheat production. Yields of 4 tons of corn and 2.2 tons of soybean have been obtained in the rainy season without irrigation. In dry season, with irrigation, 2 to 2.5 tons of wheat are obtained isolated or in rotation with corn and soybeans (Silva, 76, EMBRAPA 76).

The main factors to improve the soil fertility of the "cerrados" are phosphorus and limestone. There is a strong interaction between these two factors.

In large areas of the "cerrados" in the States of Minas Gerais, Goias and Mato Grosso there are many deposits of limestone spread in the region. So, there is no need for long distance transportation of limestone, what is very important in its cost for the farmers. More important, mines of phosphates in Brazil are located in "cerrado" region: Araxa, Patos de Minas and Tapira, in the state of Minas Gerais, and Catalao, in the State of Goias.

The clearing of "cerrado", the seed bed preparation and the mechanized farming is easier and cheap in the "cerrado" region because of the land being rather flat in large extensions, the physical properties of the soil and the large farms.

The local market for the production is growing fast since the foundation of Brasilia, where there is already a population of one million persons. There are many other cities in the "cerrado" region: Belo Horizonte, Goiania, Uberaba, Uberlandia, Sete Lagoas, Campo Grande, Patos de Minas, Anapolis, Rondonopolis and others. The population of Goias and Mato Grosso is growing very quickly due to the migration from other states.

The highway system is reasonable and there is a trend to improve because of the connections of Brasilia with all regions of the country. The farm roads are easy to be build and preserved because of the nature of the soil with good drainage and abundant material for road building and preservation.

Naturally, the existing roads will not be enough for the production of 50 million hectares but they have to be built at the same time that the production will be growing up.

Regarding the environmental conditions, there are difficulties in the climate and in the soils. The climate is the same of that of many important agricultural areas in crop production for half a century or more, in Brazil.

The main difficulty is the dry periods during the rainy season (veranicos). The vary in intensity and condition the potential crop production by direct effect or by influence on insects and diseases.

The small water holding capacity of the soils of cerrado, a very common characteristic, increases the effect of the dry periods over the yield.

It has been estimated that 8 consecutive days without rain exhausts the water capacity available for plants in the 50 cm depth of the soil.

A study of 42 years of climatological data in the region of Brasilia, has shown the frequency of dry spells presented in the Table 1.

Table 1: Frequency of dry spells ("veranicos") in rainy seasons in 42 years, in the Brasilia region (Wolf).

| Consecutive days without rain | Frequency |
|---|---|
| 8 or more | 3 per year |
| 10 or more | 2 per year |
| 13 or more | 1 per year |
| 18 or more | 2 in 7 years |
| 22 or more | 1 in 7 years |

Although there is an urgent need for agricultural research, a simple but comprehensive research, already under way, allows to establish systems of production for immediate use as was done for wheat (Silva, 76).

There is already knowledge in many crops for successful growing. There are researches and farm growing of coffee, corn, soybeans, rice, beans, cassava, sorghum, and several forages, besides large plantations of Eucaliptus and Pinus for wood and cellulose production.

There is limitation on manpower specially of trained personal; the traditional farmer of the region has not the knowledge and the experience for an intensive agricultural production. However, the Official extension services and several companies are hiring agricultural university graduates to provide assistance. In addition, the migration of farmers with experience, to the region.

The geographic position of the most important areas of the "cerrados" in the central part of the country, is a factor that makes it difficult the exportation of its production. The recent progress in the transportation of iron ore for exportation from distances over 500 km of a product of low value per ton (US$15.00), gives hopes that it

will be economical to export grains, considering also that important grain export countries have their crop production in central areas, as the United States and Canada.

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Appendix V

Resolutions of the International Workshop (Reunion Internacional de Sorgo) in Buenos Aires

1. The Resolution Committee wishes to express its appreciation to the institutions, both public and private who made this International Sorghum Workshop possible.

Contributing institutions were:

a) Secretaria de Agricultura Granderia de la Nacion

b) ASA (Asociacion de Semilleros Argentina)

c) Banco de la Nacion Argentina

d) Banco Grandero Argentino

e) Bolsa de Cereales de Buenos Aires

f) Centro de Exportadores de Cereals

g) INTA (Instituto Nacional de Tecnologia Agropecuaria Junta Nactional de Granos).

The committee would also like to thank those who assisted with the different services that made the meeting function so well.

2. It is suggested that every country of Latin America form an organization of sorghum researchers. Each of these National groups will choose a representative to facilitate the formation of an association of Sorghum Researchers for Latin America.

3. It is suggested that this same type of meeting be held once every three years and be identified by a chronological number. It is proposed that Columbia will host the next meeting in 1981. Mexico was suggested as the alternative.

4. It was suggested that every public institution propose a list of genetic material, with important agronomic traits, that is available for exchange.

5. Sorghum Breeders of Latin America are invited to contribute to Sorghum Newsletter, at the same time, it is proposed that a periodic bulletin be organized by breeders working in Latin America for the exchange of information.

6. It is suggested to include millets as a topic area in future meetings.

7. It is encouraged that a close contact be established between Institutes and breeders of Latin America and ICRISAT; this contact should materialize through exchange of genetic material and training sorghum workers of Latin America.

8. It is solicited to contemplate the possibility of ICRISAT to establish one or more Research Centers in suitable regions of Latin America.

9. It is urged that the committee organizing the next meeting try to complete the recommendations listed above.

Seed Company Representatives attending meeting in Argentina
(Company, Number of Representatives)

Argentina

| | | | |
|---|---|---|---|
| Agro-Oeste | (1) | | |
| Asgrow | (2) | | |
| Celulosa | (1) | | |
| Cargill | (3) | | |
| Ciba Geigy | (3) | | |
| Comega S.A. | (1) | | |
| Contenental S.A. | (7) | | |
| Coop. Agrop El Progreso Ltd. Saenz Peuco-chaco | | | (1) |
| Coop. Agrop Ltd. Chiff de Elerton lo | | | (1) |
| CREA Henderson - Bolivar | | | (1) |
| Criadero Continental | | | (1) |
| Craidero Morgan de Santa Ursula S.A. | | | (5) |
| Dekalb | (7) | | |
| Duperial | (1) | | |
| Forestal Pergamino S.A. | | (2) | |
| Hibridas Mac S.A. | | (2) | |
| Lineas Doradas S.C.A. | | (2) | |
| Lloreate Hnos S.R.L. | | (2) | |
| Northrup King | | (11) | |
| Panoja S.R.L. | | (1) | |
| Pioneer, Hi-Bred Seed | | (1) | |
| Produccion de Semillas | | (1) | |
| Produccion de Semillas Selectas Coop Ltd. Pergamino | | | (1) |
| Purina | | (1) | |
| Semillero "El Ceibo" | | (1) | |
| Semillero La Alborado | | (1) | |
| Semilleros "La Victoria" | | (1) | |
| Servicio de Produccion de Semillas S.A. | | | (3) |
| Tecuosurco SACIFA | | (1) | |
| | | Total | 66 |

Australia

| | | |
|---|---|---|
| Pacific Seeds (1) | Total | 1 |

Brazil

| | | |
|---|---|---|
| Agroave (1) | | |
| PROAGRO-Pineer (1) | | |
| Sementes - Conti Brasil Ltd (2) | Total | 4 |

Colombia

| | | |
|---|---|---|
| Colsemillas Ltd (1) | | |
| Prosemillas (2) | Total | 3 |

| | | | |
|---|---|---|---|
| Equador | | | |
| Semillas Certificadas Cia de Eco Mixta | (1) | Total | 1 |
| France | | | |
| Northrup King | (1) | Total | 1 |
| Uruguay | | | |
| Cabana de Estancia Nueva Mehlem | (1) | | |
| La Estanzuela | (1) | Total | 2 |
| USA | | | |
| Asgrow | (1) | | |
| Cargill | (1) | | |
| Cros hyton Seed Co | (1) | | |
| Dekalb | (2) | | |
| Funks | (1) | | |
| Growers Seed Association | (2) | | |
| Nickerson Inter Plant Breeders | (1) | | |
| Northrup King | (2) | | |
| Pioneer | (2) | | |
| Taylor Evans | (1) | Total | 14 |
| Venezuela | | | |
| Proseca | (1) | | |
| Protinal | (1) | Total | 2 |
| | | Grand Total: | 94 |

Total registered attendance at the meeting: 176

Numbers of participants from the various countries attending the meeting in Buenos Aires.

| | | |
|---|---|---|
| 1. | Argentina | 114 |
| 2. | Australia | 1 |
| 3. | Bolivia | 2 |
| 4. | Brasil | 7 |
| 5. | Colombia | 4 |
| 6. | Ecuador | 1 |
| 7. | France | 1 |
| 8. | India | 1 |
| 9. | Mexico | 3 |
| 10. | Senegal | 1 |
| 11. | Sudan | 1 |
| 12. | U.K. | 1 |
| 13. | Uruguay | 7 |
| 14. | U.S.A. | 25 |
| 15. | Venezuela | 6 |
| | | 175 |

# Notes from the International Sorghum Workshop, Buenos Aires

## March 7-12, 1978

This is a series of more or less disjointed comments but present information of some interest and usefulness.

Virus in Argentina is different than in the USA.

IS 2816C has been found resistant to downy mildew.

Sorghum actually entered Mexico in the early 1900's but picked up in usage in the 60's. Major production area in Mexico in the Bahio. Yields on production crops frequently exceed 10 tons per/ha. A lot of production in northern state in Mexico of Tamaulipas- quite a bit of production with irrigation. Sinaloas, Mexico, another important production area.

Research began in Mexico in 1945, first hybrids released in 1970-75 period. There are 20 companies in northern Mexico involved in seed production. About 1.5 million hectares in small farms where they are interested in a food type sorghum.

Research in Venezuela began in 1949 with collections made in the Central part of the country. These led to trials in 1950-52.

There is interest in using sorghum flour, to extend wheat flour.

Venezuela is being pushed into greater activity with sorghum because of the need to import greater quantities of feed and food grain.

There has been a decline in Venezuela in per hectare yield as more and more area is brought into production. There are semi arid areas with rainfall less than 500 mm.

Eleven percent of the land area in Colombia is sown. Sorghum is in the 3rd place in production following rice and corn.

The area sown has increased substantially from 1972 to 1976. Yields fluctuate from 2.2 to 2.8 ton/hect.

The major sorghum production area of Colombia appears to be in the central part of the country. Grain is being imported in increasing amounts. Producers of sorghum seed in the country registered with the government. Naitama, a released variety, is a kafir type red in colour.

Picture of crop of Naitama most impressive. Second variety shown not so impressive, seed white, many secondary tillers that come higher than the main head, companies produce hybrids from their own research. The last 3 hybrids released in the country are from these companies. Of seven hybrids that have been used all but one have come from US companies E57, from Dekalb, has contributed the most. ICA Naitama is grown on about 4 times the area of E57. Most of the grain goes into chicken feed. Eggs are a big business.

In 1976 Serena 65 and Serena have been found useful. Have made progress from a cross between these and ICA Naitama. Most of the varieties have red grain, but do have white types that appear to be of reasonable quality. Looks like yellow endosperm parentage may be involved in some crosses.

The hybrid made involving ICA Naitama is not spectacular. CK 60 x SB 65 is better but still not really good looking. No food use of sorghum in Colombia at this time. Have no technology developed for food use. Charcoal rot is a major problem.

Most of the seed used in Venezuela has come in from the USA or from US companies operating in other areas of the Americas. They have used up to 2.5 million kilos of seed and this amount may be doubled this year.

The hybrids are showing lower yields than in the more temperate countries.

The comment about lack of adaptation of US material in these more tropical areas was made.

A lot of instability is found among the hybrids introduced from temperate areas. There is a big year by year variation. Venezuelan crop improvement program about 10 years old.

There has been some trouble developing new A-B lines. They have received good material from the conversion program. Grain deterioration was mentioned to be a problem. Having a problem of nicking when they move things from the US into the Venezuelan climate. Feel that change in environment results in non uniform change in flowering between the parents. They are finding that high temperatures ($38^{o}C$) are interfering with good production unless there is an adequate amount of water. There is a dry season but because of uncertainities in the rainfall yields are always lower than they are during the wet season.

They are producing 10 to 20% of the seed used in Venezuela - the rest is imported. They have a problem with acid soil - like Brazil, very little organic matter, very low water holding capacity. There is a vast vast difference in the luxurance of crops that we see in pictures from tropical areas compared to the temperate areas.

Naitama giving good results in Venezuela, 150,000 plants/hect. best for seed production.

In conversation with people from Boliva the comment was made that the country is importing wheat and they are very interested in extending this with sorghum flour. The same thing was expressed by men from Colombia and Venezuela.

Dwarf mosaic entered the USA in 1958 was again observed 2 times in 1970. Pathological research began in Argentina in 1931.

Green bug and midge the two most important insects in North America.

Mites are a secondary pest that cause more problems if its parasites are killed. Heliothis, Spodoptera occasional pests usually not requiring insecticide control. If midge becomes serious 3 applications may be required for control - sowing date an effective means of control. Spider mites worse during periods of hot-dry weather. Green bug not only sucs juice but injects toxin; predators are effective in green bug control. These are essentially the same predators that control other aphids. Have been able to use very low level of insecticide which has retarded development of aphids but did not hurt the population of natural predators.

Insecticides are only considered when insects have reached a population size to cause economic damage - this requires field checking to be sure that this level has been reached. Using disyston to control green bug. Use of resistant types to green bug helps bring things into a better natural balance. The green bug population cannot build up to economic levels and permits a better chance for control by predators - balanced ecosystem. Host plant resistance is the best way to deal with the mite.

Finding that some non-senescent sorghums are looking good for host plant resistance against mite. George Teetes feels that there should be two head worms per head with no predators before begin to use spray. Fall army worm is the No. 1 pest in South East USA - exceeds damage caused by midge. Fall army worm damage on young plant (first 2 or 3 weeks of growth) more than on more mature plants. G. Teetes talks about using pesticides not based on number of insects present but more on level of damage to the plants themselves.

A note should be made at ICRISAT of the interest expressed at this meeting in the Sorghum and Millets Information Center. The possibility of interpretation into Sapnish and Portugese was recognized.

Most sorghum in Bolivia cultivated around Santa Cruz. There are other smaller areas in the country. There are two areas around Santa Cruz - one to the north where its fairly humid. The slides show farms

that look much like USA ie, large farms with homes on the farms. Temperatures will go to 35°C average with 65% relative humdity.

The area south of Santa Cruz is dry - semi arid with aluvial clay soils. Hot months are Dec-Jan. The summer is Oct-Feb. Winter temperatures are 21°C. About 30,000 hectares of sorghum in this area.

Have problem with weeds around Santa Cruz. Frequently use drills and machinery used for other crops for sorghum so do not have anything very fixed for sowing sorghum. Midge is the most important insect problem. Fall army worm is a problem.

Stem borer and green bugs are also a problem. Most of these pests are below economic threshold. Spodoptera is a problem. Downy mildew and birds are problems in some areas. Dr. C.E. Domanshi, Food Technologist, at the Manfedi Station in Argentina is working on extending wheat flour with sorghum. He was amazed at the grain quality in my pictures and he requested seed. Dr. Domanshi has tried making bread from high and low glutin type sorghums and has been extending wheat flour using 10, 20, 30% sorghum. He could make a good bread using 10% dilution, but the bread was no longer very good at dilutions of 20% unless the sorghum has a fair amount of glutin.

Some of these new wheats have a lower glutin content and are limited to about 15% additives. Have looked at manufacture of bisquits and find that they can have different levels of substitution for different products. The range of products normally made from wheat is substantial. Opens up the opportunity for different levels of substitution for different products. They are importing wheat in Argentina, so they are interested in extending it. As we get into more tropical countries - this seems to be an aspect of rising interest.

Martin Price, Biochemist, Purdue, indicates that the problems of stability, problems of variation in day by day analysis and between lab analysis make it difficult to work with tannins. Cooking reduces adverse dietary effects of tannins to the place that they cannot be detected. Even a high tannin sorghum if cooked would not have an adverse effect on nutrient quality.

Appendix VIII

# Growing Sorghum in Santa Cruz de la Sierra - Bolivia

In Bolivia, growing sorghum is relatively new, statistics show that the number of hectares sown, the production and conusmption are very low. However, approximate calculations have been made by different organizations and they estimate that the area sown will not exceed two million hectares and that the yield will fluctuate between 2500 to 3000 kilos per hectare.

Sorghum is cultivated mostly in the oriental area of the country and found in Santa Cruz Department. It is also planted in small areas in other valleys of the country.

In the Agricultural area of Santa Cruz Department two different zones are found:

a) North zone: Semi-humid, it corresponds to the soil system of sub tropicale forests (following the soil system "Cochrane 1973") with aluvial soils .

The climatical data recorded in the Saavedra Experiment Station shows the mean annual temperature to be 24°C , mean humidity of 65.5%, and an average rainfall of 1,205 mm per year distributed mainly during October-February.

b) South zone: Semi-dry, weather data taken from the 6 de Agosto Experiment Station in "Abapo-Izozog, located at 130 kilometers south of Santa Cruz. The soils have sedimentary aluvial formation with texture varying from loam to clay loam. Generally it is high in clay. The climate of the project area is semi-arid.

The dry season comes in winter (June - August) and the summers are hot and humid (December to February). The average annual rainfall reaches 660 mm with greatest precipation between October and February (approximately 400 to 500 mm). The average temperature in summer reaches 28°C and in winter 21°C, with an annual mean of more or less 24.5°C. The humidity varies between 55 and 75% during most of the year.

The evapotranspiration caused by the high temperature and winds, reaches 2,900 mm per year with a daily mean of 6 mm in winter and 9 mm in summer.

The wind registered during the year is typically of the Chaco. The monthly speed of the wind is about 9 km/hr. The principal direction of the wind is north-north west, and the second direction is south. These winds come in the form of unexpected gusts and they last for few seconds at a speed of 50 km/hr.

The water table averages 150 meters in depth. The water is good; the pH varies from 7.3 to 8.6.

In some zones there are Agricultural organizations. These organizations grow sorghum with difficulty because of low yields compared to cotton and sugar cane.

In the Southern zone, as a consequence of low rainfall, farmers take the risk of loosing their cotton, sugar cane and soyabean crops because of drought. As alternative crops, experiments are being undertaken with sorghum and maize. In this zone, it is our interest to reach to approximately 30,000 ha.

Experiments with the sorghum crop:

The only experiments on sorghum in Santa Cruz are undertaken at the Agricultural Experimental Station in Saavedra, and at the station in Abapo-Izozog. Some experiments are taken with farmers in isolated areas. The results till now are:

Hybrids grown in Saavedra Agr. Experiment Station. Year 1973-74

| No. | Days to flower | Plant height (m) | Yield tons/ha |
|---|---|---|---|
| DA - 41 | 60 | 1,40 | 3,68 |
| DA - 54 | 63 | 1,10 | 4,29 |
| DA - 43 | 61 | 1,70 | 4,39 |
| BB - 64 | 63 | 1,00 | 3,83 |
| DAS- 44 | 62 | 1,70 | 4,26 |

During the Agricultural year 1974-75, 33 varieties were planted at different locations; the 5 best varieties are:

| Variety | Days to fowering | Plant heigh (cm) | Yield kg/ha |
|---|---|---|---|
| G - 025 | 56 | 100 | 6.682 |
| G - 108 | 60 | 70 | 5.155 |
| G - 086 | 59 | 85 | 5.003 |
| G - 123 | 56 | 70 | 4.593 |
| G - 118 | 52 | 80 | 4.172 |

In another trial, 21 varieties of grain sorghum were tested. Characteristics of the 5 best varieties are:

| Variety | Days to flowering | Plant height (cm) | Yield tons/ha |
|---|---|---|---|
| KS - 18 | 59 | 72 | 4,59 |
| KS - 12 | 59 | 70 | 4,36 |
| KS - 24 | 56 | 75 | 4,35 |
| K - 58 | 57 | 66 | 4,22 |
| KS - 16 | 57 | 68 | 4,00 |

During the same year another trial of 17 varieties of grain sorghum were tested and the best 5 varieties are:

| Variety | Days to flowering | Plant height (cm) | Yield tons/ha |
|---|---|---|---|
| 9NK - 290A | 63 | 1,23 | 4,22 |
| 7X - 4071 | 61 | 98 | 4,05 |
| NK - 233 GB | 56 | 83 | 3,85 |
| NK - 290 | 62 | 95 | 3,81 |
| NK - 280 | 54 | 70 | 3,62 |

In earlier years trials were conducted to evaluate adaptation of materials from other countries.

In 77-78 they are undertaking 2 trials to identify grain varieties
Data for the 5 best varieties are:

| Variety | Days to flower | Plant height (m) |
|---|---|---|
| Bravis | 45 | 1,30 |
| S - 114 | 45 | 1,23 |
| Agroceres 1010 | 48 | 1,13 |
| Espanta pajaros | 49 | 1,35 |
| F - 61 | 51 | 1,38 |

Yield results will be available soon.

The records of 1973 for the Abapo-Izozog Experiment Station indicate the following:

Cultivars, plot size and yield (dried) of Sorghum

| Variety | area (ha) | Yield tons/ha |
|---|---|---|
| AKS - 614 | 9,0 | 1,04 |
| NK - 300 | 3,0 | 1,13 |
| TE - 66B | 6,7 | 0,55 |

In another trial under irrigation the Hybrid NK 300, Robusto FS - 24 gave yield 8,2; 7,6, 7,1 t/ha respectively.

The farming records of 1974 show that grain sorghum is one crop with good adaptation to the ecological condition of the project Abapo-Izozog.

This cereal is cultivated during the summer when high yields are obtained, its characteristics are resistant to drought, it responds to irrigation and is resistant to insect pests and can be cultivated like maize. Currently, a major problem is shortage of hybrid seeds.

## Sowing period

The sowing period is November and December in the north as well as south.

## Sowing system

Recommendations from the Saavedra Experiment Station are to sow in rows 40 to 60 cm apart to enable the control of weeds. At the Abapo project they use a planter which is also used for cotton and soyabean, spacing can be changed from 17 cm between rows to 92 cm, between rows. The sorghum farmers now use distances to fit their planter.

## Sowing Density

Depending on seed quality, farmers sow 8 to 12 kg of seed per hectare.

Weed Control

There are no herbicides used to control weeds; the cultivator is mostly being used. It is considered that weeds, both grassy and broad leaf, are the major limiting factor in sorghum production in Santa Cruz.

Insects and diseases

As sorghum is a new crop in Santa Cruz, not many insects pests are present. However, eleven insects have been registered that attack the sorghum plant. The latest observations indicate that the more important insect are: Sorghum midge (Contarinia sorghicola), (Spodoptera frugiperda), (Diatraea saccharalis), Schizaphis graminum). Until this year, 1978, none of these insects have affected the crop economically (nor have been registered as insects of importance economically). In trials planted in Saavedra Experiment Station in 1978 Schizaphis graminum caused considerable damage in some varieties.

Other important insects are the following:

Heliothis zea

Leptoglossus phyllopus

Pococera atrimentalis

Sathrobrota sp.

Chaetocnema sp.

Pentatomidae.

Observations in IDIN (International Disease and Insect Nursery) of Texas A & M University indicated that varieties resistant to (Shizaphis graminum) in Texas are also resistant to this species in Bolivia. But, in a rating for damage of 1 good to 9 bad, the major damage was 5. Some entries were badly damaged by (Spodoptera frugiperda;20% of the leaves were lost); other varieties had no damage. It seems that it will be worthwhile to evaluate this type of damage in years to come.

The Sorghum Midge Nursery of Texas A & M University was completely destroyed by birds in 1976-77, and the nursery of this year was not yet ripe when this paper was written. However, birds were the most serious pests observed in our plots in Saavedra in 1976-77 and 1977-78. Even "bird resistant" types were damaged by the birds.

In Abapo, results indicate that Spodoptera and Heliothis were damaging during the vegetative phase, but it was not necessary to use insecticides.

The most common disease is the leaf spot caused by Cercospora, although, other diseases have been identified caused by Sclerospora and Scleroptora 'Downy Mildew'.

Other pests of consideration are several bird species, the only way to control bird damage is by the period of sowing.

Harvest

All harvesting, at the commercial scale, is done by machine.

Commercially (business)

The total production of sorghum is destined for the animal feed industry. The cost of sorghum is US $ 3.5 for 46 kilos (one quintal).

Appendix IX

Distribution of rainfall Araripina, Pernambuco: (Av. of 13 years)

| | | | |
|---|---|---|---|
| Jan | 120 mm | July 10 mm | |
| Feb | 140 | Aug 5 | |
| Mar | 190 | Sep 2 | Total 802 mm |
| Apr | 90 | Oct 25 | |
| May | 40 | Nov 60 | |
| Jun | 30 | Dec 90 | |

Rainfall, Temperature and Evaporation in Janauba (San Francisco River Valley) in Northern Minas Gerais) (1931-1960)

| Month | Rainfall mm | Temperature °C | Evaporation mm |
|---|---|---|---|
| Jan | 147.2 | 25.1 | 80.7 |
| Feb | 104.8 | 25.3 | 74.8 |
| Mar | 103.1 | 25.2 | 79.2 |
| Apr | 52.3 | 24.6 | 86.6 |
| May | 11.4 | 23.3 | 100.5 |
| Jun | 1.4 | 22.2 | 112.7 |
| Jul | 0.5 | 22.0 | 136.9 |
| Aug | 1.5 | 23.4 | 167.8 |
| Sep | 15.6 | 25.5 | 177.6 |
| Oct | 57.4 | 26.4 | 167.3 |
| Nov | 164.9 | 25.2 | 98.5 |
| Dec | 216.6 | 24.7 | 71.6 |
| Total | 866.7 | | |

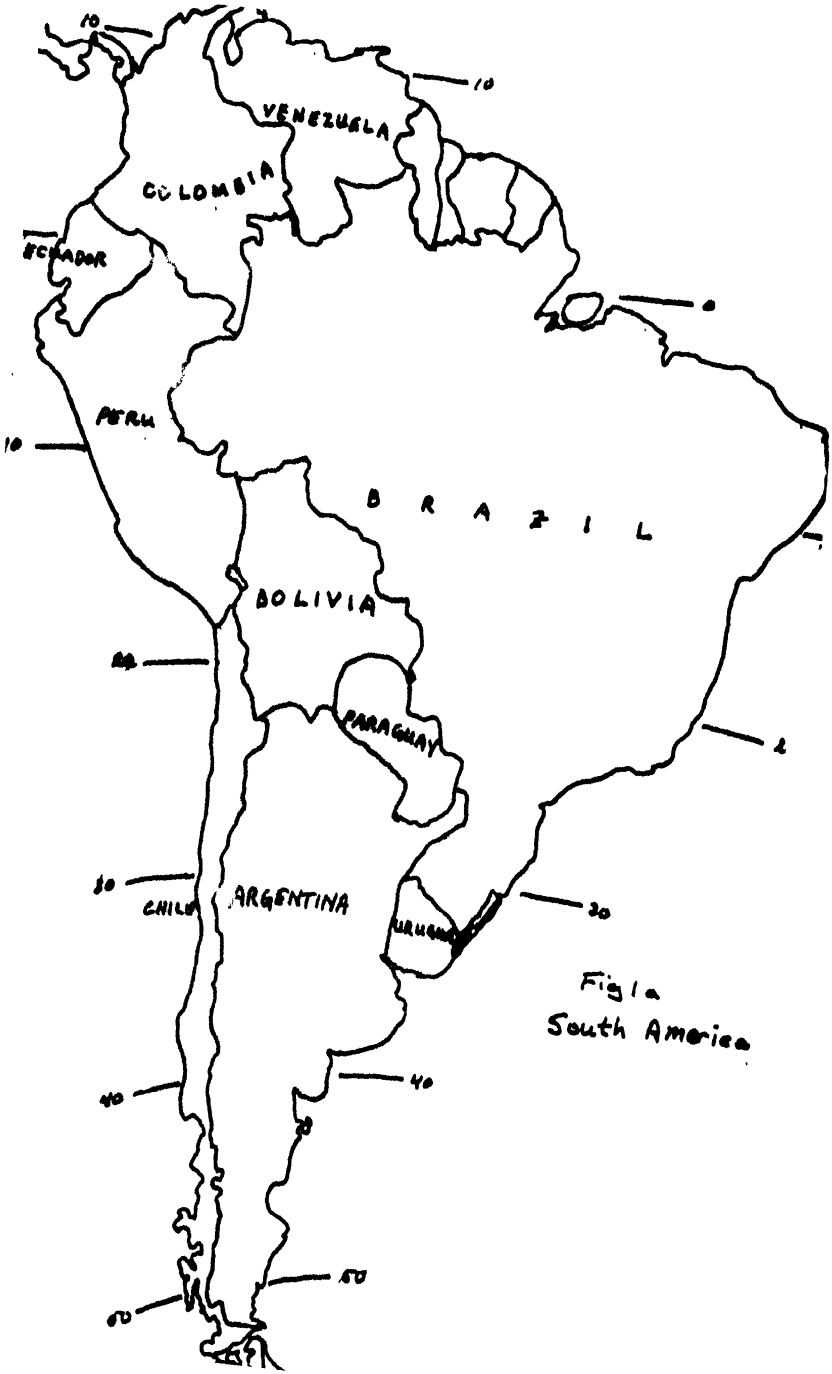



Fig 1a
South America

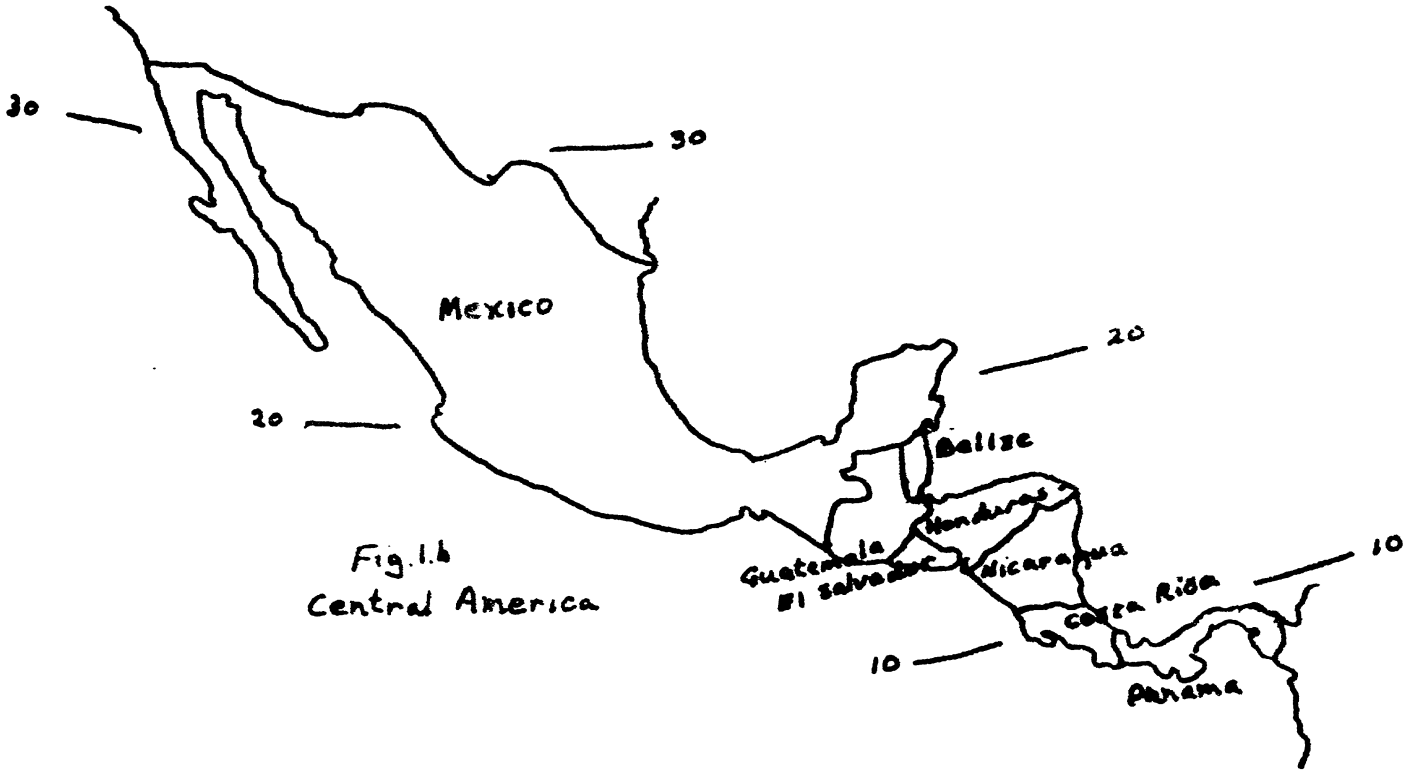


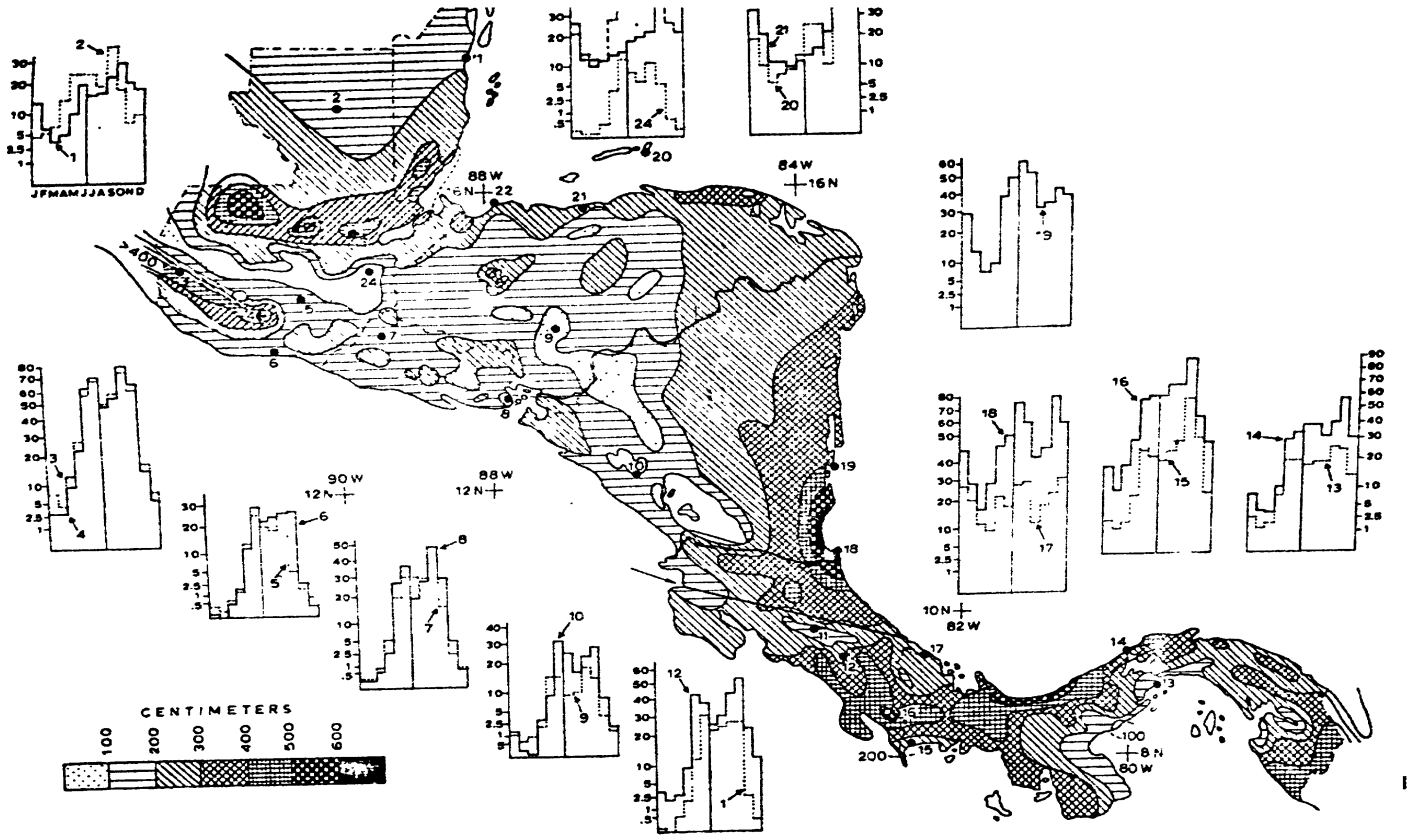

Fig. 1.6
Central America


PARA
MARANHAO
CEARA
RIO GRAND DO NORTE
PARAIBA
PERNAMBUCO
ALAGOAS
SERGIPE
PIAUI
ACRE
GOIAS
BAHIA
MINAS GERAIS
SAO PAULO
PARANA
SANTA CATARINA
RIO GRANDE DO SUL
BRASIL

Fig. 2

Fig 3
AVERAGE ANNUAL PRECIPITATION

0 - 250 MILLIMETRES
250 - 500
500 - 750
750 - 1000
1000 - 1500
1500 AND OVER




Mean annual rainfall (mm) in Central America.

Fig. 4

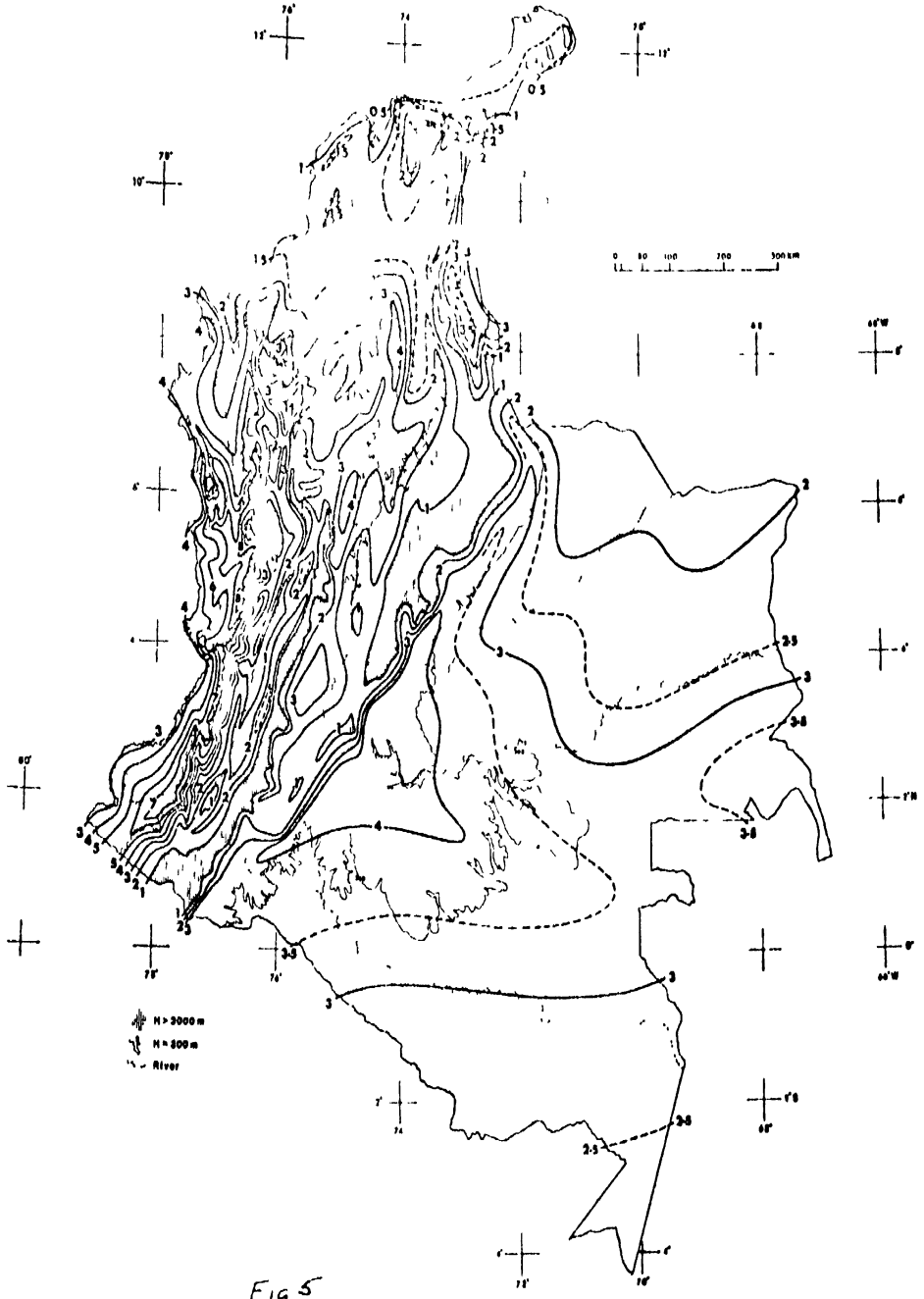



Fig 5

Annual total rainfall (m), Colombia Mean based on period 1931 60.

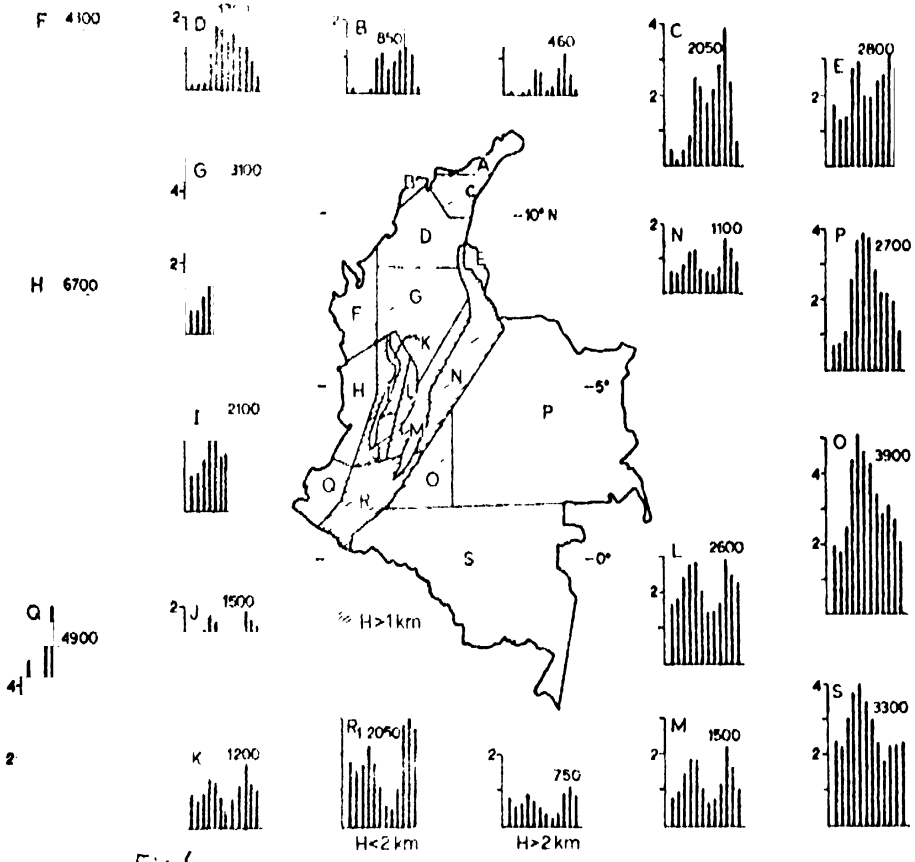



Fig. 6

Annual distribution of rainfall for various sections of Colombia. Ordinate values in mm/100, annual totals in mm. Based on period 1931–60 (certain data subjected to reduction)

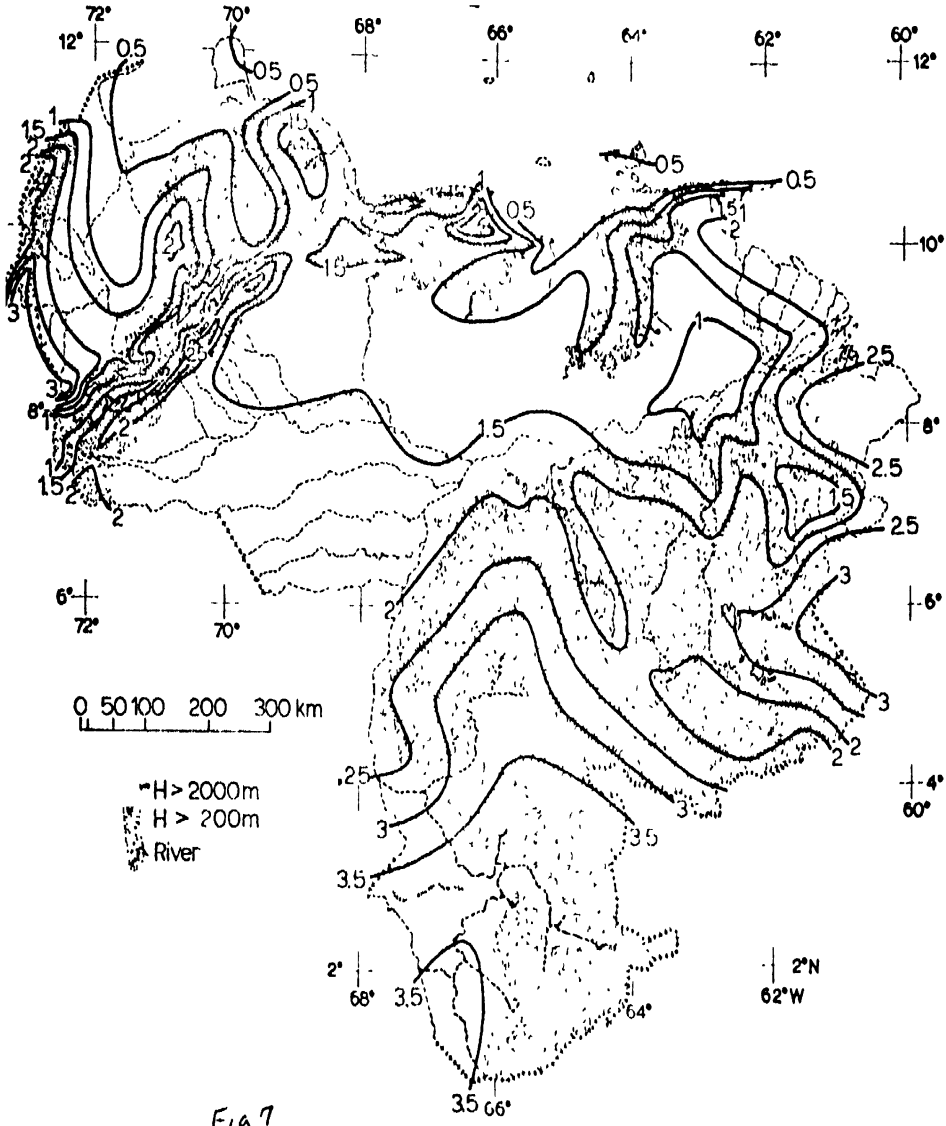



Fig. 7

Annual total rainfall (m), Venezuela. Mean based on period 1931–60.

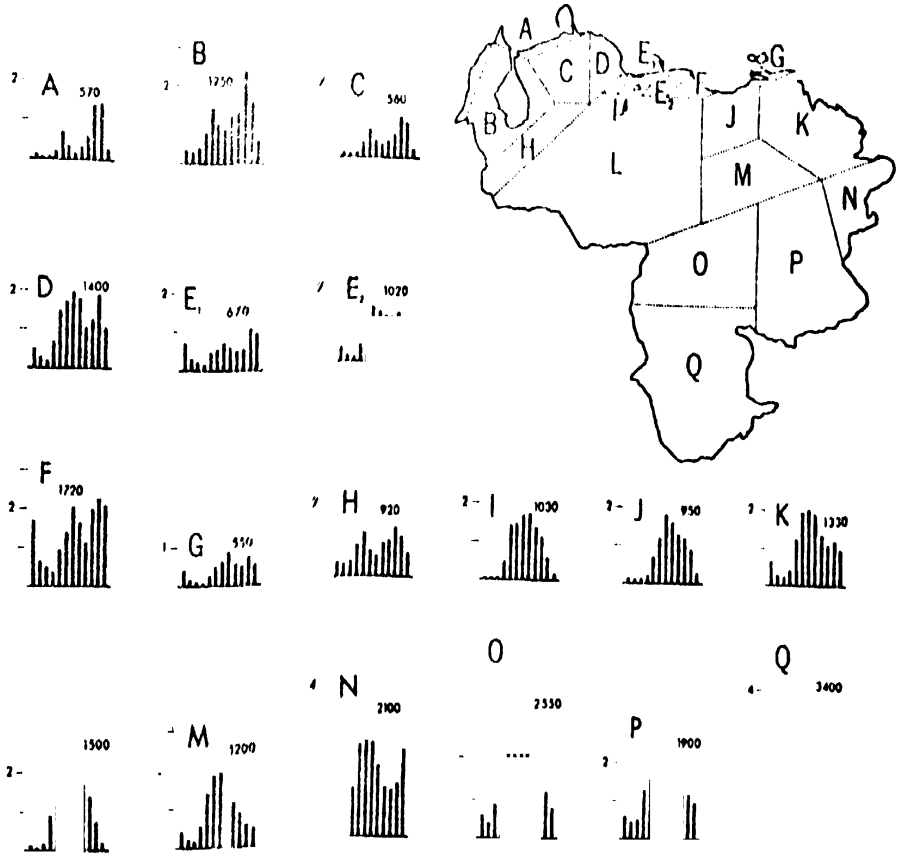



Fig. 8 Annual distribution of rainfall for various sections of Venezuela. Ordinate values in mm/100, annual totals in mm. Based on period 1931-60 (certain data subjected to reduction).

Brasil

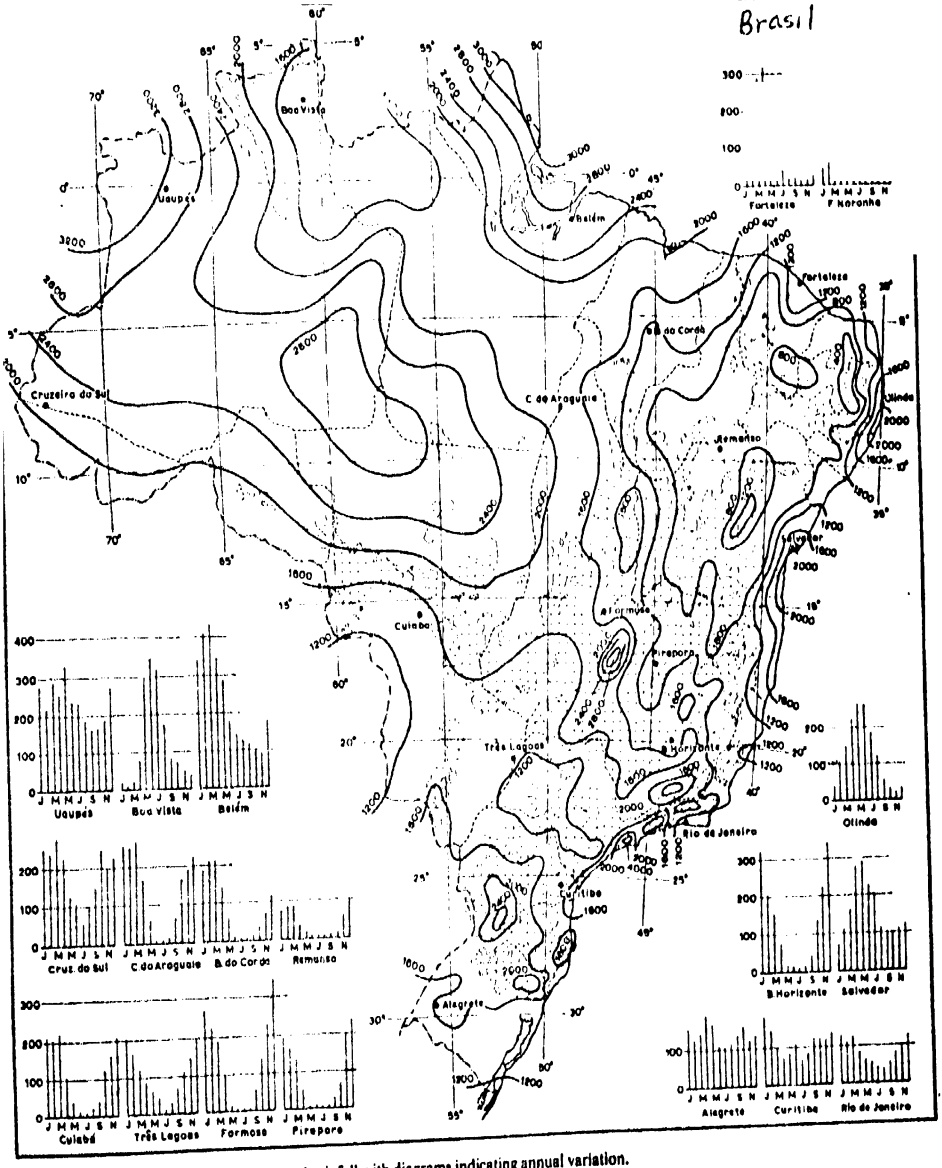



Fig. 4 Total annual rainfall with diagrams indicating annual variation.

Brasil

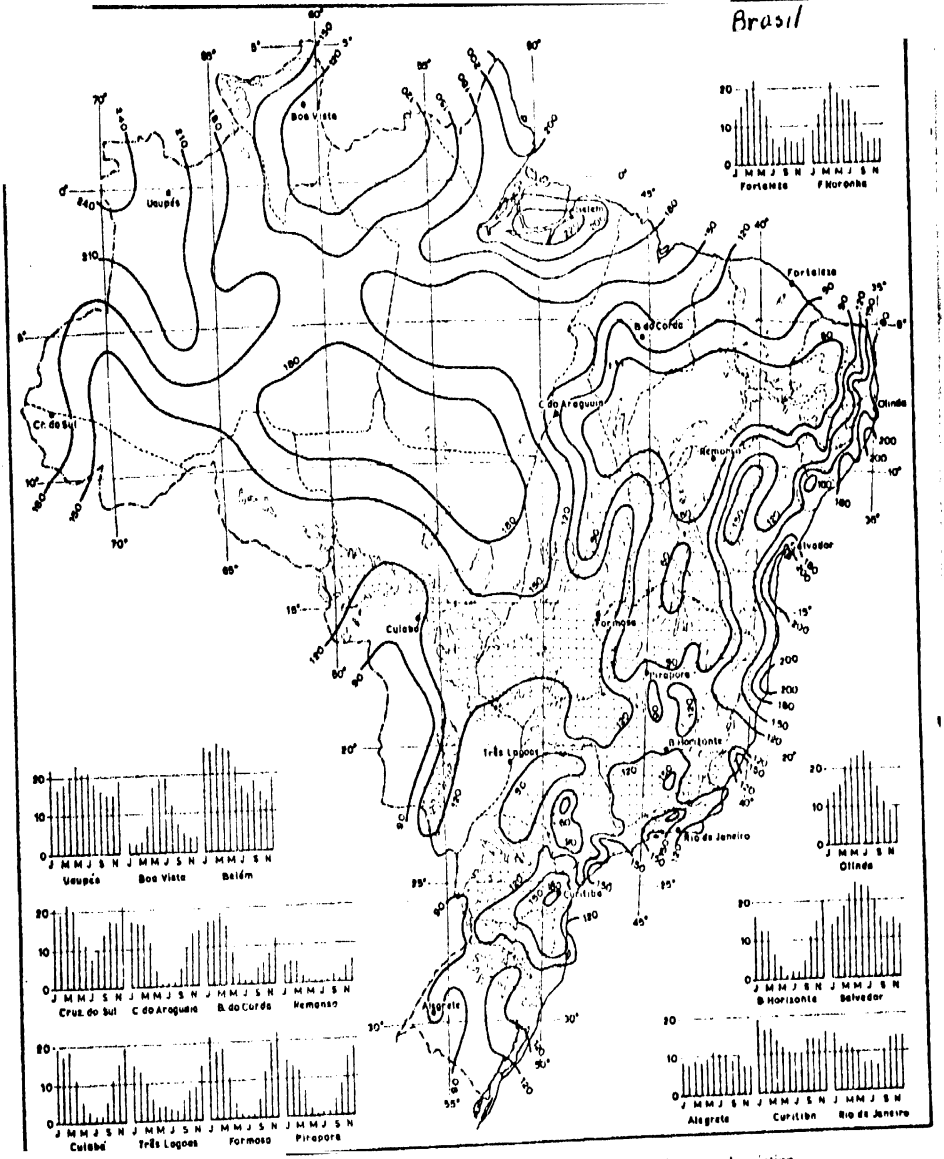
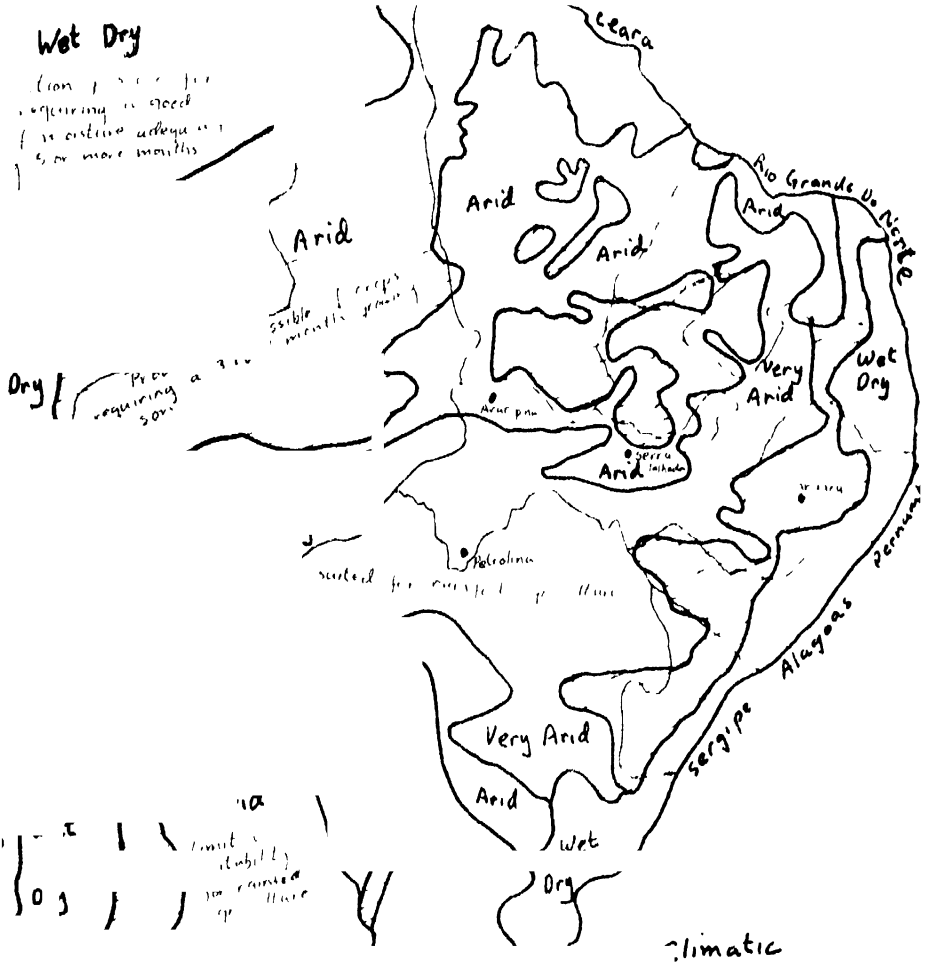



Fig. 10 Number of days with precipitation ( ≥0.1 mm), with diagrams indicating annual variation.




Climatic classification for North East Brazil

Semi Arid

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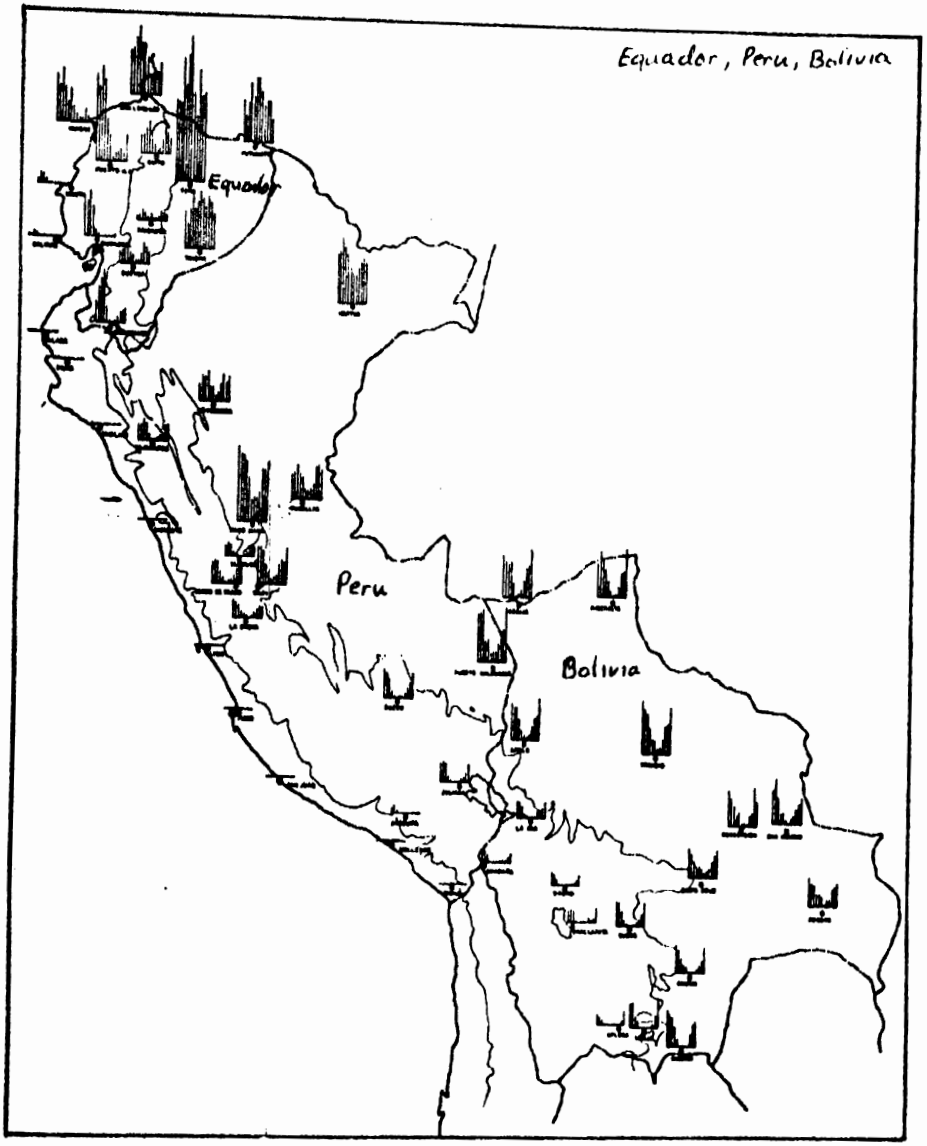



Fig. 12 Seasonal distribution of rainfall. Thin line: 2,000 m above sea level.

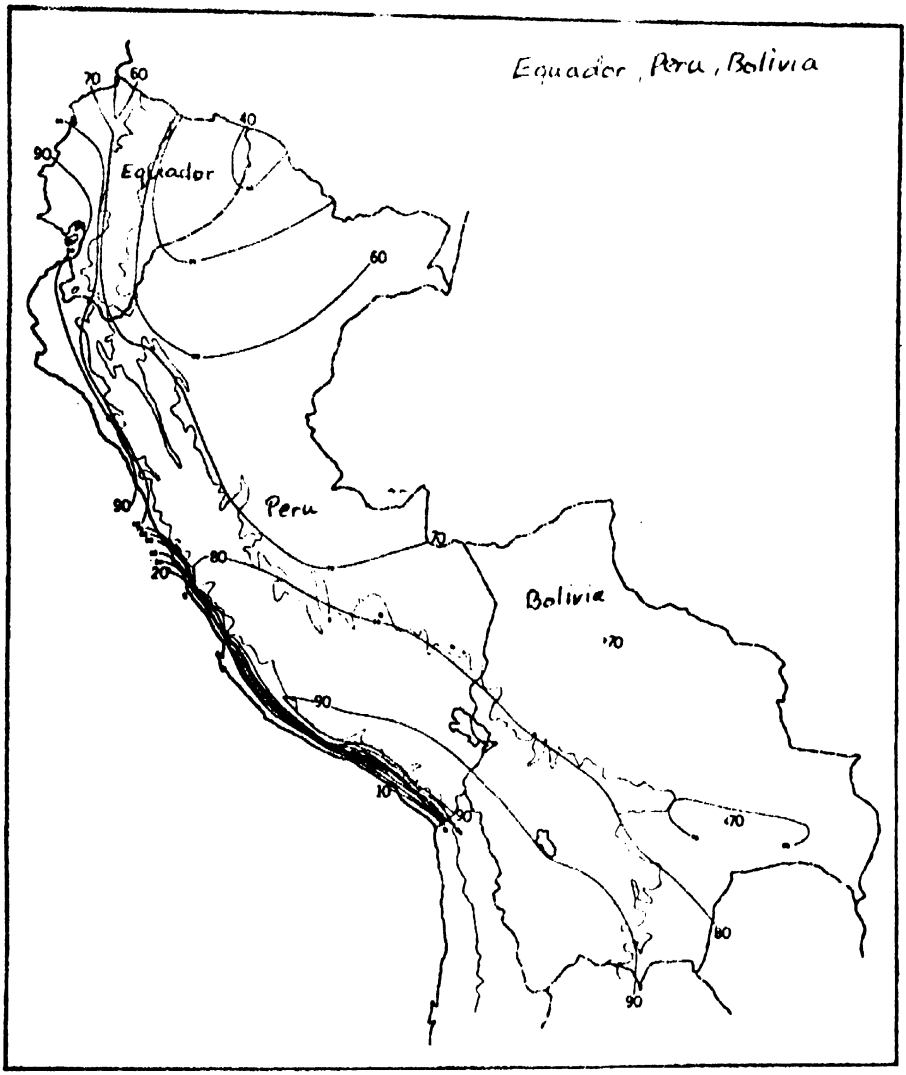
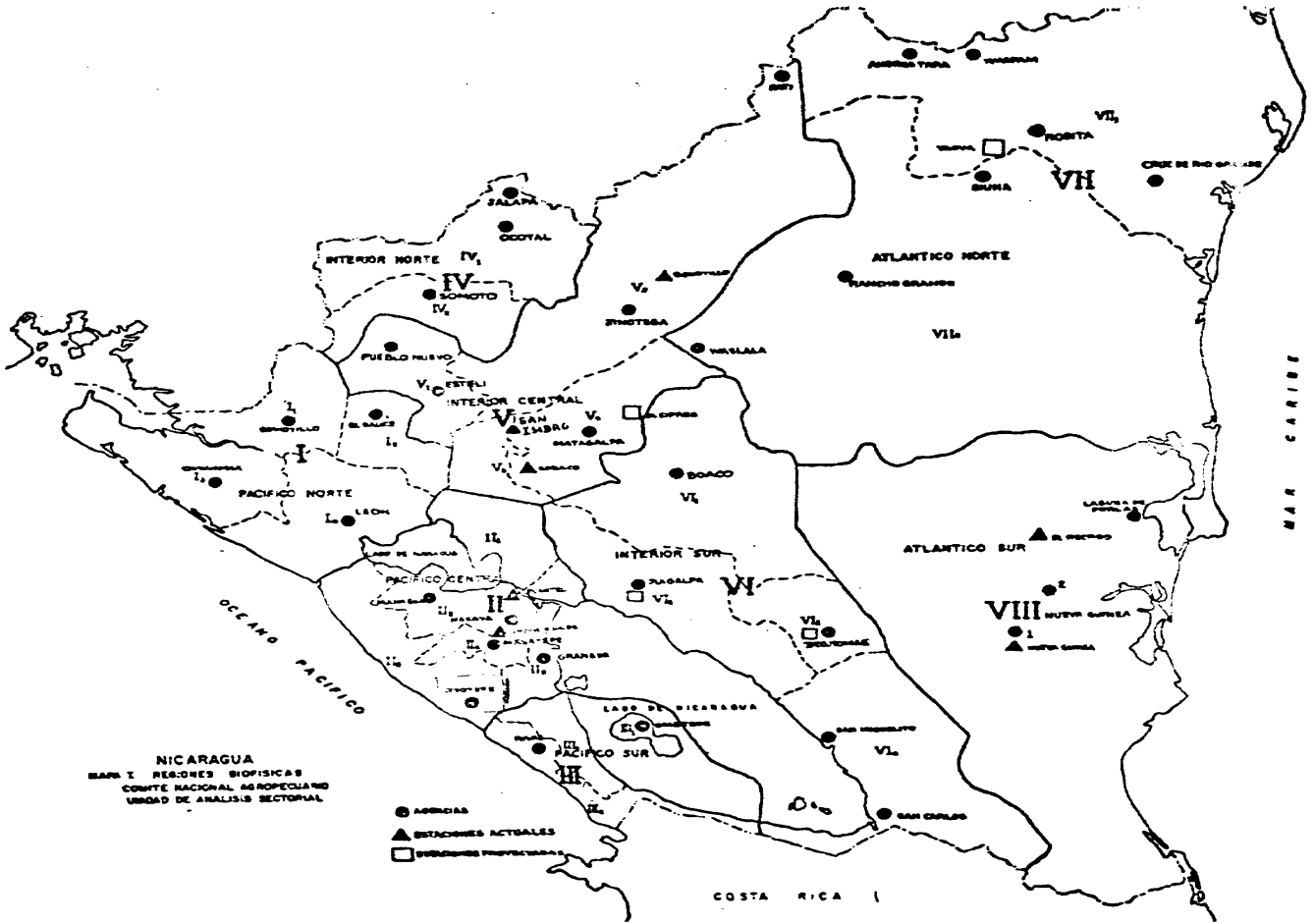



Fig 13 Percentage of annual rainfall occurring in the six months November-April. Thin dotted line: 2,000 m above sea level.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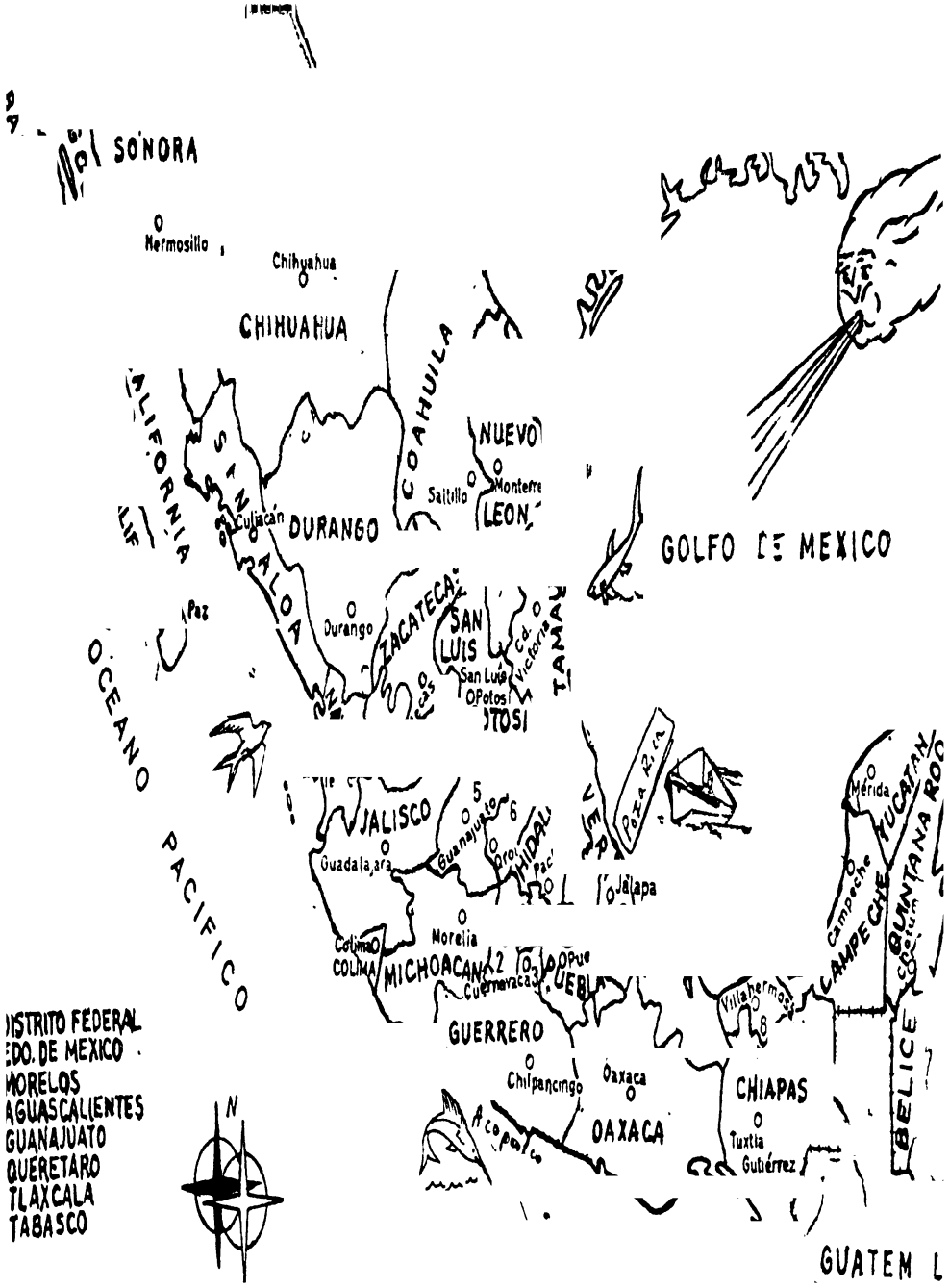
SAN CARLOS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