A Research and Network Strategy for Sustainable Sorghum and Pearl Millet Production Systems for Latin America

International Crops Research Institute for the Semi-Arid Tropics
Centro Internacional de Agricultura Tropical

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Abstract

The workshop on a Research and Network Strategy for Sustainable Sorghum and Pearl Millet production systems for Latin America was attended by 28 scientists from four countries in the region — Colombia, Brazil, Venezuela and Honduras — and from ICRISAT and CIAT The workshop reviewed the research work carried out under the project funded by IDB: project milestones, methodology adapted, and progress made to achieve the milestones; network trials results and status of sorghum and pearl millet research in the region. Further, the workshop identified bottlenecks in returning data, formulated the methods of trials or seed distribution, identified coordinators for each country, and outlined the research thrusts for further research. These include: extending the research to other zones (fertile areas and drought - prone areas) besides acid savanna soils; enhancing research on pearl millet to 30% (sorghum 70%) from the present 10%; nutrient uptake efficiency (sorghum); and use of pearl millet as soil organic content enricher. This publication contains the presentations made at the meeting and a summary of the recommendations. It thus provides an overview of the current status of the research in the IDB -funded project, and discusses the problems and prospects for sorghum and pearl millet production in the region.

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A Research and Network Strategy for Sustainable Sorghum and Pearl Millet Production Systems for Latin America

Proceedings of the Workshop

Edited by

Belum V.S. Reddy, Hernan Ceballos, and Rodomiro Ortiz

24-26 November 1998

Experimental Center 'La Libertad', Villavicencio, Meta, Colombia

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Foreword

Rodomiro Ortiz[1]

Vast plain areas in valleys in Colombia, Venezuela, and Brazil in Latin America and Honduras in Central America have been under agro-pastoral systems traditionally used for livestock production. These areas can be utilized in more productive and sustainable ways by introducing various crops. The Inter-American Development Bank (IDB) supported a limited program of introducing and screening improved sorghum and pearl millet breeding materials developed over the last 22 years at ICRISAT for tolerance to Al^{3+} toxicity and resistance to leaf diseases prevalent in the acid-soil savannas. The IDB grant for Phase I, 1996-97, totalled US$ 0.25m. This initiative was extremely productive and cost effective, and prompted IDB to support a second phase (US$ 0.25 million during 1998-99) for further screening and development of materials tolerant to acid soils, for training, and networking among scientists in the region.

This program was successfully managed by a sorghum breeder from ICRISAT through periodic visits to the region. After establishing contact with the scientists at CIAT, and the national programs of Colombia, Brazil, Venezuela (and Honduras which joined as an associate member), a large number of improved sorghum A/B- and R-lines, varieties, local landraces and ms_3 populations, and pearl millet populations, open-pollinated varieties, and A/B-lines were introduced from ICRISAT-Patancheru, India and screened successfully at Quilichao, Matazul, and Carimagua in Colombia for tolerance to Al^{3+} toxicity and for resistance to leaf diseases for over two seasons in 1996 and 1997. The selected grain sorghum A/B-lines, R-lines, forage sorghum varieties, and forage pearl millet populations, open pollinated varieties, and A/B-lines were distributed as network trials to the partners in the region in the second phase in 1997 and 1998.

This workshop and its proceedings are among the more tangible outcomes of the thrust in the second phase of the Latin American sorghum research and network project.We are happy to note that the workshop was conducted at La Libertad, the headquarters of Agricultural Research for Region 8 in Colombia, a member of the network. Twenty eight scientists from all the four members countries participated in the workshop. Nine papers were presented by the national scientists on the current status of research in sorghum and pearl millet and their experiences with the network trials. Four papers were presented by ICRISAT scientists on the research efforts in identifying sorghum and pearl millet materials tolerant to acid soils and the bottlenecks in conducting and managing the network trials. The editorial efforts to put together the papers presented at the workshop with abstracts in the Spanish and the full papers in English are highly commendable and we believe that this will help scientists in the region.

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1. Director, Genetic Resources and Enhancement Program (GREP), ICRISAT, Patancheru 502 324, Andhra Pradesh, India

We consider the workshop to have been highly effective in analyzing the outputs of the research of the regional sorghum project in relation to the approved project proposal. The bottlenecks in receiving the data from the network trials were identified. Procedures were formulated to distribute the seed to the private and public sectors in the member countries, and new research thrusts in these two crops in the region were identified. The workshop proceedings effectively provide an overview of the current status of research in sorghum and pearl millet in the region and in particular in the IDB-funded sorghum project.

Introduction to the Workshop

Belum V S Reddy[1]

A Research and Network Strategy for Sustainable Sorghum and Pearl Millet Production Systems for Latin America Project was initiated towards the end of 1995 at the International Center for Tropical Agriculture (CIAT, its Spanish acronym) Cali, Colombia by introducing advanced sorghum and pearl millet breeding material from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) Patancheru, India. The target areas are acid-soil savannas *(Llanos* or Cerrados) in Brazil, Colombia, and Venezuela. Bolivia initially showed interest, but later withdrew from the network.

Dr. C. T. Hash will deal with the objectives and the technical aspects of the program. I will confine myself to outlining the logistics.

ICRISAT provided the support by sparing a senior visiting scientist as available funding was not sufficient to station a scientist in the region. This scientist is responsible for the execution of the project activities and achievement of the stated project objectives through frequent visits. A full-time technician stationed at CIAT has been provided with on-site supervision by a senior CIAT scientist. This team thus supported the work of the project.

Sorghum male-sterile lines, restorer lines, grain varieties, and forage sorghum and pearl millet genotypes introduced from ICRISAT were screened under acid-soil conditions over the last seven seasons spanning 3 years. The resulting promising materials were supplied to the member countries as entries in the network trials for further testing and evaluation of local adaptation.

This workshop involves scientists from the member countries and also scientists from Honduras. It is one of the major project activities, aimed at sharing the results and experiences of network trials. This workshop was thus organized with the help of network member countries, particularly Colombia. The program was formulated in a manner such that it would facilitate exchange of information on the network and the status of sorghum and pearl millet research in each member country. Also, the workshop provides an opportunity to observe various bred materials (sorghum and pearl millet) evaluated in the field.

1.Senior scientist, International Crops Research Institute tor the Semi-Arid Tropics (ICRISAT), Patancheru 502 324, Andhra Pradesh, India

Session I: Inaugural Session

Welcome Remarks

Jaime Jose Triana Restrepo[1]

En nombre de la Corporación Colombiana de Investigación Agropecuaria (CORPOICA), me gustaría darles una cálida bienvenida a nuestra Sede Regional. Es un gran placer para mi tener la oportunidad de expresar estas pocas palabras en la ceremonia de apertura de presente taller sobre Investigación y Estrategias de Red para la Producción Sostenible de Sorgo y Millo Perla en Latino América.

Como Uds. bien saben, los trópicos se caracterizan por la abundancia de suelos ácidos. En el caso particular de Latino América, unas 860 millones de hectáreas de sabanas con suelos extremadamente ácidos restan aún por ser incorporadas a la agricultura. En Colombia, las sabanas se caracterizan por la baja fertilidad de sus suelos, los que son pobres en nutrientes esenciales. También tienen bajo pH, altos niveles de aluminio intercambiable y una estructura frágil. Sin embargo, también ofrecen algunas ventajas para la agricultura sostenible como lluvias abundantes y bien distribuidas entre los meses de abril y noviembre, y una topografía plana. La región abarca unas 26 millones de hectáreas, de las cuales 53% están subutilizadas, a pesar del buen drenaje de sus suelos. El principal uso de la tierra es para ganadería, con tecnologías de bajos insumos y productividad limitada. El aprovechamiento adecuado de esos suelos requiere del establecimiento de una agricultura tropical, para desarrollar una tecnología poco costosa, pero viable, que incluya a especies vegetales y cultivares que puedan tolerar altas concentraciones de Al en el suelo, y con capacidad de absorber eficientemente los nutrientes. Otras necesidades son las relacionadas a la preparación del suelo para que ésta incremente la estabilidad de los agregados del mismo, minimizando su erosión y lavado.

Las sabanas comprenden una región extremadamente importante para la economía de nuestro país, y que ha recibido en el pasado una contribución valiosa por parte de ICA y el CIAT. La búsqueda de sistemas de producción sostenibles de alimentos, ha sido liderada por CORPOICA, quien ha logrado progresos mediante la integración de equipos multidiciplinarios de investigación. La colaboración con centros internacionales como el CIAT, CIMMYT, INTSORMIL y, ahora, ICRISAT, nos ha permitido desarrollar y liberar germoplasma de cultivos forrajeros y de grano tolerantes a los suelos ácidos: variedades de arroz, soya, maíz y sorgo, así como especies forrajeras gramíneas y leguminosas.

1. Director, Region 8, CORPOICA, C.I. La Libertad, Villavicencio, Colombia, A.A. 3129

En el corto plazo estaremos trabajando para fortalecer nuestra relación con los Centros Internacionales de Investigación Agrícola, como ICRISAT, y los Centros Nacionales de Latino América. Mediante esta colaboración intentaremos mejorar la calidad de nuestra investigación, a través del intercambio de germoplasma. Esperamos que disfruten su estadía con nosotros y que esta experiencia sea muy productiva para todos los participantes.

On behalf of the Colombian Corporation for Agriculture and Livestock Research (CORPOICA), I would like to extend to you a warm welcome to CORPOICA headquarters. It is a great pleasure for me to have the opportunity to say a few words at the opening of this workshop on Research and Network Strategy for Sustainable Sorghum and Pearl Millet Production Systems for Latin America.

As you are aware, the tropics are well endowed with acid soils and this is particularly so in Latin America where nearly 860 million hectares of extremely acid savannas remain to be developed for arable agriculture. In Colombia the savannas are characterized by low-fertility soils that are poor in essential nutrients. They also have low pH, high exchangeable aluminum and fragile soil structure. Nevertheless, they offer certain advantages for sustainable agriculture, such as plenty rainfall and adequate distribution between April and November, and flat topography. The entire region comprises about 26 million hectares, of which 53% are well drained and underused. The land is predominantly used for extensive cattle raising, with low-input technology and low productivity. The efficient use of these soils requires establishing a tropical agriculture in order to develop a highly viable and cheap technology, including crop species and cultivars that can tolerate high concentrations of Al^{3+} while efficiently absorbing nutrients. Other needs are land preparation practices that increase the stability of soil aggregates and minimize erosion and runoff. The savannas comprise a region of great importance for the country, and have received in the past invaluable research contributions from ICA and OAT. The search for a sustainable food crop production system has been led by CORPOICA, where an integrated, multidisciplinary approach has been successfully adopted. Collaborative research with international centers such as CIAT, CIMMYT, INTSORMIL, and now ICRISAT has led us to develop and release crops and forage species tolerant to acid soils: rice, soybean, maize and sorghum varieties; and grass and legume species for forage.

In the near future we look forward to implementing the links between International Research Centers like ICRISAT, and the National Centers from Latin America. With this collaboration we will attempt to improve the quality of research by enhancing germplasm exchange. We hope you will enjoy your stay with us, and that this will also be a rewarding experience for all the participants.

A General Vision of CORPOICA Region 8 in the Eastern Plains of Colombia

M. Dario Leal[1]

Resumen

La Corporación Colombiana de Investigación Agropecuaria (CORPOICA) es una corporación sin ánimo de lucro, cuyo objetivo principal es generar investigación y transferencia de tecnología para el sector agropecuario con la ayuda y participación del sector público y privado. En el ámbito central, está conformado por entidades gubernamentales, agremiaciones, universidades y empresas privadas que determinan el desarrollo, mejoramiento y manejo del sector agropecuario del país. A escala regional, 21 centros experimentales de investigación abarcan todas las zonas geográficas del país. Dentro de las regionales, la Regional Ocho con sede en Villavicencio Departamento del Meta, se plantea como una de las más importante y de mayor proyección del país, debido a su amplio potencial agrícola y ganadero. La ubicación geográfica, climatologia y principales focos de investigación de la regional son brevemente descritos.

CORPOICA is a non-profit mixed corporation created by the National Government of Colombia, based on the Science and Technology Law, to strengthen and direct the research and transfer of technology to the farming sector with the help and participation of the private sector.Their mission is based on four basic objectives:

- To improve the competitiveness of the farming sector
- To develop an equitable distribution of technology benefits to the farming sector
- To achieve an efficient sustainable farming production through rational use of natural resources
- To develop and manage research and technology capacity in a manner that will allow the country to generate the needed farming technology

CORPOICA is built around a central organization formed by representation from the main government institutions, the farming associations, experimental research centers, territorial entities, and universities. Similarly, at the regional level, CORPOICA manages 21 regional research centers that cover countrywide ecosystems. Region 8 targets the southeast of Colombia, which is formed by the Oriental plains (*Llanos),* Guaviare department and the Amazon region. Geographically, Region 8 is located between 2° 30' and 7° North latitude and between 67° 30'and 74° East longitude.

1. Research Coodinator, Region 8, CORPOICA, C. I. La Libertad, Villavicencio, A.A 3129, Colombia

The Oriental plains region (Colombian Orinioquia) are bounded omthe west by the right strip of the Oriental Mountain range from the Macarena Sierra until the Arauca River, on the south from the north bank of Guaviare river up to the mouth of the Orinoco River; on the north along the Venezuelan frontier. This region includes the Arauca, Casanare, Meta and Vichada departments. Of the 76 agroecological zones in the country, 34 are in this region. The region comprises 23% of the country's total area, amounting to 26 million hectares, which covers:

- the Piedemont plains which extend from the Macarena Sierra to the Arauca River mouth;
- the flooded Orinoquia or poorly drained savanna: plains in the Casanare and Arauca departments;
- the well drained Orinoquia or lowlands which extend from Puerto Lopez municipality along the right side of the Meta River to the Orinoco river mouth;
- the Orinoquia strip; and
- the swamp or marshlands zone.

Orinoco lowland altitude ranges between 500 m above sea level at the Piedemont and 50 meters above sea level at the Meta River joins the Orinoco River. In general these lowlands have a plain topography with 1 to 3% slope. However, dissected lowlands can have slopes of 12 to 25% or higher. Piedemont and the hillsides range in altitude between 800 and 2500 m above sea level.

Relative humidity levels range between 96% in winter to 76% in summer. Rains have a mono-modal distribution, where the rainy season is May to October and the dry season, December to March. Annual rainfall varies from 3500 mm close to the mountains to 2800 mm in central Orinoquia, and 2000 mm in Arauca and Vichada departments. The mean temperature fluctuates between 24 and 28°C, with the highest temperatures in the northwest of Arauca and the east of Vichada departments.

Region 8 has developed and transferred technology in such agrosystems as cotton, rice, rice-grasses, rice-maize-soybean, rice-soybean-grasses, fruits, sugarcane, farming animals, and forage. The mission of this center is to improve the quality of life of the people in the region through development, adaptation, validation and transfer of technologies that increase production and make farming competitive in the Oriental plains of Colombia, while protecting the natural resources of the region.

A Research and Network Strategy for Sustainable Sorghum Production Systems for Latin America: Project Outline

C.T. Hash[1]

Resumen

Este artículo informa acerca de los objetivos, los participantes y las metas de las fases I y II de este proyecto. La fase I (1996-1998) incluye la introducción y prueba de las líneas andro-estériles y restauradores de fertilidad, así como de las variedades de polinización libre de sorgo y millo perla en los suelos ácidos de la región de los Llanos. Igualmente se informa acerca de la red de participantes que compartieron estos materiales en la región y los datos obtenidos en estos ensayos experimentales. La fase II (1998-1999) incluye (i) el entrenamiento e intercambio científico entre la región e ICRISAT, para de este manera obtener un mejor conocimento de las actividades de la investigación en el sorgo y el millo perla; (ii) la selección de materiales de alto rendimiento en los suelos ácidos; y (iii) los ensayos experimentales de estos materiales en diferentes sistemas de producción en los Llanos. Este artículo discute el rol de la resistencia a enfermedades en los suelos ácidos y la resistencia a las enfermedades. La participación de científicos de Brasil, Colombia, Honduras y Venezuela en este proyecto financiado por el Banco Inter-Americano de Desarollo (BID) se menciona en este reporte. La meta del proyecto es lograr dentro de nueve años un valor económico adicional de US $ 40 millones a través de esta investigación en red.

Background

For the period 1996-97, the Inter-American Development Bank (IDB) provided US$250,000 for a limited program of sorghum improvement research in tropical Latin America. This project fell under the umbrella of the Systemwide Ecoregional Program for Enhancing Agricultural Research in Tropical America, coordinated by CIAT. Partners in this project include ICRISAT, CIAT, and most importantly, the national programs of Brazil, Colombia, Honduras, and Venezuela. This initial phase was extremely productive and cost effective, stimulating IDB to support a second phase for 1998-99.

1. Principal Scientist (Breeding), Genetic Resources and Enhancement Program (GREP), International Crops Research institute for the Semi-Arid Tropics (ICRISAT), Patancheru 502 324, Andhra Pradesh, India

Phase I: Objectives and Achievements

The objectives of the first phase of this project were to assemble, multiply, and evaluate sorghum (95%) and pearl millet (5%) breeding lines and germplasm accessions, seeking improved sources of acid-soil tolerance/foliar disease resistance, and agronomic eliteness for adaptation to the savannas of Latin America. During this period we introduced 777 sorghum restorer lines, 378 sorghum maintainer lines, and 8 control entries from ICRISAT, Patancheru to Colombia in late 1995. These materials were multiplied and evaluated at CIAT, Palmira, and we selected 269 restorers, 228 maintainers, and 33 forage lines for rust resistance and high-yield potential. These genetic materials were subsequently evaluated multilocationally for acid-soil tolerance, and distributed to national programs in the network.

The project also initiated the development of an effective network for the evaluation of progenies, sharing of information, data and materials, and enhancement of knowledge on sorghum (and pearl millet) improvement for the region. Scientific exchange during this first phase of the project focused primarily on genetic improvement of sorghum and pearl millet. Two scientists from the region, Jaime Bernal of CORPOICA and Pedro Garcia of FONAIAP, visited ICRISAT, Patancheru in 1996, to become familiar with the range of genetic materials and screening methods available there for sorghum and pearl millet. In addition, they established at Patancheru a hydroponics screening procedure that allows rapid identification of genetic materials lacking adaptation to high levels of aluminum saturation. This allows ICRISAT to more efficiently choose additional sorghum and pearl millet genotypes for possible introduction and evaluation here in Latin America. This was followed in 1997-98 by visits by Latin American sorghum scientists to ICRISAT, Patancheru (e.g., Andres Felipe Rangel of ICRISAT/CIAT) and visits by several ICRISAT scientists to Latin America.

Phase II: Objectives

The networking objectives of phase I continue to be important in phase II; this workshop and its proceedings are among the more tangible outcomes of this thrust. In addition, there are programs to develop high-yielding seed parents, open-pollinated varieties, and restorer lines in a range of plant heights, maturities, tillering abilities, and grain types with:

- tolerance to acid soils (high Al^{3+} saturation),
- tolerance to low phosphorus availability, and
- resistance to prevalent foliar diseases.

Products of this breeding program will be evaluated in a crop-livestock production systems context in collaboration with CIAT and national program production agronomists.

Scope of Phase II activities

This collaborative project now emphasizes:

- assisting national sorghum programs in Latin America through revitalization of the regional sorghum improvement network;
- training (at ICRISAT, Patancheru) of selected sorghum improvement scientists from the region (e.g., Alfonzo Gonzalez of CORPOICA, and Paulo Caesar Magalhaes, and Fredolino dos Santos of CNPMS/EMBRAPA); and
- greater emphasis on disease resistance to address the major weakness of the acid-soil tolerant sorghum germplasm previously available in the region.

Project partners and contacts

The institutions most actively participating in this project and the contact persons in each are as follows:

- INTSORMIL/CIAT/CORPOICA. Lynn Gourley and Jaime Bernal
- CNPMS/EMBRAPA. Robert Schaffert
- ICRISAT. Belum VS. Reddy and C. T Hash
- OAT. Carlos Iglesias, John Miles, Hernan Ceballos, Richard Thomas

Additional participants are the national programs in Venezuela and Honduras, with the following institutions taking the lead:

- FONAIAP
- Escuela Agricola Panamericana, Zamorano

Researchable biotic production constraints

The primary biotic constraints to sorghum (and pearl millet) production in this region, for which improved resistance levels are sought in this project, are

- insects (*Diatrea* and *Spodoptera),*
- foliar diseases *(Colletotrichum* and *Cercospora),* and,
- panicle diseases *(Fusarium)*.

Seasons for seed multiplication and evaluation

Although the current phase of this project is intended to last 2 years, we expect to make substantial progress towards the objectives listed above by using three seasons each year for seed multiplication and evaluation:

- January/February. Off-season activities (primarily seed multiplication) at CIAT, Palmira;
- May/June sowings: Evaluate for acid-soil tolerance / foliar and panicle disease resistance by field screening in the *Llanos;* and
- September/October sowings: Evaluate for acid-soil tolerance / terminal drought stress tolerance by field screening in the *Llanos.*

Project Goals

If, in the medium term, this project is to be seen as successful, we must accomplish the following:

- combine increased agricultural productivity of the acid-soil savannas with improved environmental protection, and strengthened national program research capacity on sorghum (and pearl millet) improvement;
- release of elite sorghum (and pearl millet) cultivars adapted to the acid-soil savannas of Latin America within 5 years;
- achieve an increase in annual sorghum (and pearl millet) production of 100 000 ha in the acid-soil savannas of Latin America within 10 years, stimulating agriculture and livestock production on five times this area, and thus,
- within 9 years, achieve an economic value of US $40 million from the research investment made in this project.

I believe that we can achieve these goals without much difficulty, given the rate of progress thus far.

Workshop Purpose

The workshop aims to provide an opportunity for frank and open scientific exchange among participating partners to monitor progress in this project, to demonstrate performance of genetic materials in the field at two sites here in the Colombian acid-soil savannas, and—perhaps most importantly—to plan future research collaboration.

Session II: Collaborators' Reports

Sorghum and Pearl Millet in Brazil: Results and Prospects

Fredolino G. dos Santos[1], Gilson E. V Pitta[1], Robert E. Schaffert[2], Jose A. S. Rodrigues[1], and Carlos R. Casela[1]

Resumen

Durante la última década, la demanda de grano en Brasil se ha incrementado notoriamente. Sin embargo la producción nacional no cubre la demanda de las empresas avícolas, y ganaderas. En la actualidad el área sembrada en sorgo (Sorghum bicolor) *ubicada comúnmente en la parte centro occidental y sur oriental del Brasil se ha incrementado igualmente, debido principalmente a sus bajos costos de producción asociados a la fertilidad residual dejada por el cultivo previo de soya* (Glycine max). *El programa de mejoramiento del programa nacional de maíz y sorgo tiene como objetivo principal la evaluación, selección, y adaptación de materiales mejorados paras diferentes zonas productoras, en especial los cerrados Brasileños. Los objetivos y metas del programa de mejoramiento son descritas posteriormente*

The demand for grain in Brazil has increased substantially during the last decade. Although maize represents about 40% of the nation's total grain production, the consumption is higher than the supply. The needs of segments such as poultry, swine and cattle in addition to that for human consumption contribute to this huge demand. These needs must be met by alternative means if the deficit is to be reduced.

In this context, sorghum is of great importance. Estimates of 10% to 20% of the total grain produced in Brazil (80 million tons) are suggestive of the potential of this crop to fulfill this demand. The market price difference of sorghum in Brazil generally ranges between 20% to 30% of that of maize, but depending on the maize production, this difference may be reduced significantly.

The niche for sorghum production areas more recently has been concentrated in the West Central Region and in the traditional Southeast areas. The production system in both the areas is basically sequential, after the soybean crop, which is called "end-season cropping". This system accounts for over 90% of the national sorghum production and usually the seeds are sown during mid-February, soon after the harvest of soybean. This system usually requires no basal fertilizers for sorghum, due to residual fertility from the summer cropping. Only side dressing with nitrogen is required. Current statistics indicate that close to one million tons of sorghum grain has been produced this year, amounting to a production increase of more than two-fold compared to 1997.

1 Sorghum Breeder, and

2 Sorghum Program Leader, Centra Nacional de Pesquisa de Milho e Sorgo, EMBRAPA, Sete lagoas MG, Brazil, CP 151

The sorghum breeding program of the National Maize and Sorghum Research Center has focused on the development of populations, male-sterile inbred lines, and R-lines more tolerant to biotic and abiotic stresses. One of the main research targets has been the determination of the relationship of soil acidity with crop growth in the *Cerrado* areas.

This multidisciplinary effort resulted in the identification and improvement of sources of aluminium-tolerant genotypes and also the more efficient use of certain important crop-growth nutrients in these areas, such as phosphorus and nitrogen. In parallel to mineral stress studies, it was observed that the combinations between A x R lines allowed for the identification of genotypes more tolerant to anthracnose (*Colletotrichum graminicola).* Seventy inbred lines were selected for green bug (*Schizaphis graminum)* tolerance and transferred to the elite lines of the breeding program. The evaluation of sources for tolerance to ergot (*Claviceps africana),* completes the current phase of research concerned with important diseases and insect pests of sorghum.

Thirty sorghum hybrids are being evaluated in the field this year. Four hybrids with great adaptability and high grain-yield potential were released; another two will be released shortly. Three hybrids and three varieties for high quality forage were also released.

As a result of the interaction between EMBRAPA and the private seed companies in Brazil, a franchising system was developed. Currently, close to 30% of the all commercial seeds sold in Brazil are products of EMBRAPA's research.

Sorghum and Pearl Millet Prospects in Pernambuco State (Brazil Northeast Region)

Jose Nildo Tabosa[1] and Ana Rita de Moraes Brandao Brito[1]

Resumen

Pernambuco es uno de los Estados más grandes de la región Noreste del Brasil, y de mayor importancia agropecuaria, debido a su potencial ganadero (ganado de carne y leche) y agrícola (producción de materias primas para concentrados animales). Sin embargo, el patrón errático de las lluvias y los períodos extensos de sequía, reducen ostensiblemente su productividad y suministro continuo de alimentos (pastos, granos, etc.). Cultivos como sorgo y millo perla (para grano y forraje) representan un alto potencial de uso, para la alimentación de animales (ensilaje, pastoreo) y la producción de concentrados, debido a su adaptabilidad a condiciones de sequía comparados con cultivos como el maíz.

Desarrollo de materiales de sorgo para grano y forraje, liberación de materiales adaptados a las diferentes condiciones climatológicas de la región, la eficiencia en el uso del agua y el uso de nutrientes, entre otros, hacen parte de la agenda de trabajos realizados por el IPA-(Empresa Pernambucana de Pesquisa Agropecuaria) en la región.

Characterization of the Region

Brazil has a territorial area of 8 511 965 km^2, distributed across five vast regions: north, northeast, southeast, south, and central west. Among these, the northeast region with 1 547 867 km^2 includes nine states of the Federation: Maranhao, Piaui, Ceara, Rio Grande do Norte, Paraiba, Pernambuco, Alagoas, Sergipe, and Bahia. The Pernambuco state has a surface area of 98 938 km^2 (6.38 % of the surface of the northeast region). The state has a longitudinal configuration, extending 748 km from the Atlantic coast to its western borders. The coastline runs along 187 km and the largest north-south distance in the state is 240 km, giving rise to three clearly defined geographical landscapes: "litoral mata" or coastal forest (10 278 km^2), "agreste" or semi-arid region (24 490 km^2), and "sertao" or arid region (63 210 km^2). These distinct regions constitute the Pernambuco state, and these are further distinguished into homogeneous microregions.

The "sertao" region is subdivided into six homogeneous microregions, all of them geographically located in the arid and semi-arid parts. The mean annual precipitation in that region is around 650 mm. About 50% of the rainfall occurs over a short spell of about 3 months and is highly erratic. The high temperatures and low relative humidity during summer results in potentially high rates of evapotranspiration, which may be higher than the water availability.

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The "agreste" physiographical region is subdivided into six homogeneous microregions which include subhumid and semi-arid areas. In this region, the mean annual precipitation varies from 700 to 1200 mm (Censo Agropecuario, 1995).

Importance of Sorghum and Millet in the Region: Current Situation and Prospects

There is evidence that the level of animal production in tropical regions is inferior to that in temperate areas. This is associated with the quality of the tropical forage crops that have high growth and lignification rates during the rainy season and low productivity potential during the dry summer period.

The bovine population of the state of Pernambuco state is about 1.86 million, of which 56% is located in the "agreste" region and 36% in the "sertao" region. The main purpose of cattle breeding in the "sertao" is meat production, while in the "agreste" is milk production. The milk production in this region accounts for 75% of the total of milk produced in the state. In these regions, despite the low observed precipitation levels, about 70% of the rainfall occurs in the first 4 months of the year. Higher temperatures and the lower relative air humidity occur during the dry season. This leads to a potential evapotranspiration rate higher than the water availability rates, making the hydric deficit the main limiting factor for plant growth. The resulting shortage of roughage during the dry period of the year affects bovine herds drastically, particularly in terms of dairy output. To minimize the deficit in milk production during this period, the state of Pernambuco imports concentrate from other states of the Federation and also from other countries.

The main factor limiting livestock performance in the semi-arid region is the shortage of roughage during the dry period of the year. This is worse in the semi-arid area of Pernambuco, where 83% of the physical area of the state is characterized as semi-arid and where the adverse climate has been decisively identified as a limitation to forage production (Johnson, 1978; Duke, 1984). Forage sorghum may constitute a strategic alternative because of its xerophytic characteristics, broad adaptation, and the great variety of ways it can be used (Lira et al., 1989).

Though sorghum is widely adapted, it is usually cultivated in high-temperature conditions and semi-arid environments. Compared with corn, the sorghum root system is more highly developed, reaching a greater depth and occupying a greater volume of the soil. Water-stress may stimulate root development. It has been observed that sorghum requires less water than maize to produce the same amount of dry matter (332 versus 368 kg H_20 kg^{-1} dry matter). The greatest advantage of sorghum over corn lies in its ability to slow its metabolism during the dry period, restarting its growth when the conditions are again favorable (Tabosa et al., 1987). Independent of the crop's potential adaptation to the semi-arid conditions, it can be used as forage, grain, straw, hay and silage, and for grazing (Tabosa et al., 1990).

In this region, other than sorghum, pearl millet crop may also serve as a viable alternative due to its drought tolerance, high forage yield, and multiple forms of utilization (Pontes, 1997; Lima, 1998). The Pernambuco state imports grain from other regions of Brazil as well as other countries. Every year 900 000 t of maize (grain) is imported, and 60% of this is used as poultry feed. Pernambuco state is the highest sorghum importer of the northeast region (Table 1). Maize production in Pernambuco is about 200 000 t, with yield levels of 700 kg ha^{-1}. There is evidence that grain sorghum can contribute towards manufacture of animal feed concentrates, and reduce the state's import burden of maize.

The *Araripe* plateau has a very large area for grain sorghum production in the Pernambuco region (Table 2). This occupies an area of approximately 1 million ha, covering parts of Pernambuco, Ceara, and Piaui. It is characterized as a highland plain region, where dystrophic red yellow latosols and/or halic soil prevail, and agriculture is totally mechanized, as shown in the grain sorghum harvest area in the northeast region in each state of Brazil (Table 3), where the sorghum areas are very small compared with maize which covers 300 000 ha in Pernambuco alone.

IPA's Research Results in Pernambuco State

- Recommendation for the semi-arid region of grain sorghum cultivars with grain yield potential of 4-5 t ha^{-1} (experimental levels);
- Recommendation of forage sorghum varieties tolerant to water stress, with high dry-matter yield for silage production;
- Development of sudan grass materials with salinity tolerance for hay production;
- Recommendation of pearl millet (forage millet) for the semi-arid region;
- Development of forage sorghum materials with high water-use efficiency

The research activities were developed and conducted under field conditions in the mandated area of IPA in the"agreste" and "sertao" regions of Pernambuco State. The geo-environmental characterization of these localities is shown in Table 4.

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Table 1. Grain sorghum consumption ('000t) by various sectors in the northeast region of Brazil.

State	Poultry	Livestock	Industry	Total
Bahia	216	45	54	315
Sergipe	48	6	14	68
Alagoas	32	17	10	59
Pernambuco	576	90	230	896
Paraiba	140	28	264	432
Rg. Norte	48	22	10	80
Ceara	360	52	60	472
Piaui	50	32	18	100
Maranhao	102	35	26	163
Total	1572	327	686	2585

Source: Associacao Avicola de Pernambuco - Avipe, 1997.

Table 2. Physical characteristics of Araripe plateau area.

	Physical area (ha)		
State	Eastern	Western	Total
Piaui		63000	63000
Ceara	305 500	290000	595 500
Pernambuco	51 900	275000	326900
Total	357400	628000	985400

Source: Zoneamento Agroecol6gico do Nordeste (EMBRAPA-CRATSA, 1993).

Table 3. Grain sorghum area harvested in the northeast region of Brazil, 1985-95.

	Harvest area (ha)					
Year	Piaui	Ceara	Rg. Norte	Pernambuco .	Bahia	Total
1985	4588	4 830	9 884	11 306	18 753	53 693
1986	1939	1007	14216	5 003	31 601	43 768
1987	-	804	5 516	2 176	13 130	21 626
1988	-	1010	16 449	3 916	9211	30 586
1989	-	-	8 805	2 525	31 301	42 621
1990	-	-	867	1 500	14 757	17 124
1991	-	-	9 560	1 225	20 655	31 510
1992	-	-	6 340	2 350	39 387	48 077
1993	-	-	-	-	16 075	16 075
1994	-	434	3 656	925	18 146	27 595
1995	-	394	4 144	584	22 473	27 595

Source: Anuano Estatfstico do Brazil, 1996.

Table 4. Geo-environmental characterization of experimental locations in the semi-arid region of Pernambuco state, Brazil.

	Locations				
Parameter	Caruaru	Sao bento do UNA	Arcoverde	Serra Talhada	Araripina
Latitude	08°34'38" S	08°31'16"S	08°25'00" S	07°59'00" S	07°29'00" S
Longitude	38°00' WGr	36°33' WGr	37°04' WGr	38°19'16"WGr	40°36'WGr
Altitude	537 m	650 m	664 m	500 m	816 m
Annual precipitation	657 mm	655 mm	*666* mm	680 mm	743 mm
Climatic type	SAM[1]	SAM	SAM	SAM	SAMS[2]

1. SAM - Semi-arid megathermic.
2. SAMS - Semi-arid mesothermic.
Sources: Anuario Estatistico de Pernambuco, 1991; EMBRAPA, 1993.

Current Status of Venezuelan Research on Grain Sorghum Cultivars Tolerant to Acid-Soil Conditions

Pedro Jose Garcia[1]

Resumen

Los suelos ácidos ocupan una gran extensión del territorio Venezolano. Estos suelos se caracterizan por su bajo pH (menor de 5.5), diferentes niveles de saturación de aluminio (entre 20 y 70%), baja concentración y retención de nutrientes al lavado. No obstante sus restricciones químicas, la expansión de la frontera agrícola ha ocasionado ha inclusión de dichas áreas en los sistemas de producción. Lo anterior la generado una alta demanda de materiales mejorados y adaptados que permitan una producción sostenible.

Incrementos en las áreas cultivadas en sorgo y maíz, en zonas comúnmente utilizadas para ganadería extensiva, hacen prever la necesidad de investigación especialmente en la identificación de germoplasma con tolerancia a la acidez del suelo. Desde 1992 diversos genotipos de maíz han sido probados bajo condiciones de acidez del suelo, sin embargo, pocos trabajos han sido realizados en sorgo.

El inicio de un programa de mejoramiento y evaluación de materiales de sorgo adaptados a las condiciones de acidez del suelo es brevemente descrito. Así mismo, se plantea la posible utilización de millo perla como alternativa forrajera en la región.

Venezuela has a wide variety of soil types, but predominant are soils with acidity, leaching, and low nutrient levels. Crop cultivation has begun to extend to these soils and the trend is likely to continue. Farmers require high-yielding cultivars that require low inputs on these soils. Breeding efforts should be directed towards the selection of genotypes with desirable agronomic performance under these adverse soil conditions.

A recent survey has shown that around 70% of the potentially exploitable soils in Venezuela have acidity and nutrient problems. Nevertheless, the acidity of Venezuelan soils is not related to high aluminum [Al^{3+}] concentrations as is the case in a majority of South American tropical soils. Acidity is a major problem in the Central Plains of Venezuela *(Llanos Centrales)* where plateaux and hills predominante. The plateaux have sandy and clayey sandy loam soils with pH below 5.5 and 50-70% Al^{3+} saturation. In the hilly areas, soil textures are fine with pH of 5.0 to 5.5 and less than 20% Al^{+3} saturation.

On the western plains (Portuguesa and Barinas states), soils have low slopes (0.2 to 0.3%) and heavy textures. Acidity problems exist in the valleys, where soils have 20 to 50% of Al^{3+} saturation and pH below 5.0.

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Most of these areas are used for beef and milk production but a significant portion is shifting to corn and sorghum production. The same areas are also used for corn and grain sorghum in a double-cropping pattern. Corn is sown during April-May and grain sorghum during September-November. This second crop utilizes the residual soil moisture from the rainy season.

Grain sorghum is sown in two well-defined areas: The Central Plains (Guarico and Aragua states) and the Western plains (Portuguesa and Barinas states). These two areas accounted for about 80% of the national grain sorghum production, that is, about 400 000 metric tons. About 200 000 ha are planted to grain sorghum each year in Venezuela.

FONAIAP has been interested in developing research projects oriented toward selection of grain sorghum genotypes adapted to acid-soil conditions. This objective has been partially achieved for corn through research projects started in 1992. In Venezuela, research on grain sorghum production for acid soil has only recently begun. In 1998, we received from Colombia, materials for three experiments containing B-, R-, and forage lines for evaluation under our conditions. Unfortunately, these experiments were not sown because the seed materials were received in February (after the normal sowing date). However, this material was planted recently in an area with acid-soil conditions.

In September 1998, we received materials from ICRISAT/CIAT, Colombia and one experiment was sown in October 1998. The delay was due to unfavorable weather conditions which prevented land preparation.

Pearl millet production is limited in Venezuela since it is used only as a cover crop in some areas susceptible to erosion. However, we think pigeonpea has potential for exploitation in animal-production areas (beef and milk production) to complement the existing forage. Once animal producers are aware of the utility of this crop in animal feeding, we are sure they would consider its inclusion in their production systems.

Honduras Sorghum Project

Hector Sierra[1] and Rafael A. Mateo[1]

Resumen

Sorgo es el tercer cultivo de mayor importancia en Centro América después del maíz y el frijol. Su producción promedia anual es de 1466 kg. por hectárea. Diferentes tipos de sorgo son utilizados, dependiendo del tipo de agricultor (razas nativas, variedades e híbridos).

La investigación y mejoramiento de sorgo en Centro América son realizados principalmente en Honduras (ZAMORANO) con el apoyo del Programa Centroamericano de Investigación de INTSORMIL. Detalles de las principales áreas de investigación son descritos a continuación.

Sorghum is the third most important grain crop in Central America after maize and beans. The area under sorghum in 1997 was 283 202 ha with a average grain yield of 1466 kg ha^{-1} The most common cropping system in many Central American countries is maize intercropped with landrace sorghums called *"maicillos criollos".* These tropical sorghums are 3 - 4 m tall, drought tolerant, and photoperiod sensitive. Although maicillos have very low grain yield they are widely grown on about 235 000 ha (83% of the total area under sorghum production in Central America).

Three types of grain sorghum materials are grown in Central America. Very small producers primarily grow *maicillos criollos* and/or indigenous landraces unique to Central America, on hillsides. Larger producers throughout Central America grow hybrids produced and marketed by private industry.

The INTSORMIL Central American Regional Program is based at the Pan-American Agricultural School (EAP), in Honduras. This central location provides the opportunity to conduct sorghum research in Honduras, and through outreach and networking to evaluate new technologies throughout Central America and interact with the private seed industry.

Research is conducted in several areas:

Tropical sorghum conservation and enhancement

Alongside *in-situ* conservation and enhancement of local landrace sorghum populations, advanced technologies are promoted so as to shift production from a tradition-based to a science-based industry.

Commercial hybrid performance tests

This testing program provides an excellent source of information about the commercial hybrids available to Central American sorghum producers. The test is conducted in 10 locations in Central America, 2 in Mexico, and 2 in the Dominican Republic.

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Entomology research

Entomology research is conducted in collaboration with Mississippi State University and the plant protection department at EAP. Previous research has focused primarily on the insect complex in the *maicillos* and the study of sorghum midge (*Stenodiplosis sorghicola)* in Nicaragua.

Plant pathology research

Several diseases offset sorghum production in Central America. These include sorghum downy mildew *[Peronosclerospora sorghi),* anthracnose *[Colletotrichum graminicola),* leaf blight *(Exerohilum turcicum),* and ergot *(Claviceps africana).* Collaborative research has been initiated between Texas A & M University, INTSORMIL and the Pan-American Agriculture School to study these diseases in Central America.

Grain quality research

Farmers on the Pacific coast of Central America have started planting sorghum along with maize to ensure grain production for tortillas and forage. During severe drought, grain sorghum has been found useful. Farmers have improved their sorghum landraces over centuries by mass selection. We are now using pure-line and pedigree selection to improve *maicillos,* which are tested for grain and tortilla quality.

Collaboration with Soil Management Program

The Soil Management Program, in collaboration with INTSORMIL, is conducting research on the steep land areas of southern Honduras to measure the impact of soil conservation techniques on sorghum production.

Training and education

The project awards two scholarships each year to EAP students to conduct research in different areas related to the sorghum crop.

Sorghum Breeding for Acid Soils in Colombia

Jaime Humberto Bernal[1]

Resumen

Con el propósito de incorporar a los sistemas nacionales de producción agrícola, aproximadamente dos millones de hectáres de los Llanos Orientales de Colombia, caracterizadas por sus suelos ácidos, se desarrolló un proyecto con INTSORMIL en el año 1983. El objetivo principal fue el de establecer un programa regional para el desarrollo de variedades e híbridos con tolerancia a, por lo menos, 60% de saturación de Al^{3+} del suelo. Luego de evaluar cerca de 6000 genotipos de sorgo de la colección mundial, en CIAT - Quilichao y CORPOICA - La Libertad, se confirmó que sólo 8% de las líneas tenían la capacidad de crecer adecuadamente en suelos con saturación de aluminio superior al 65%, y que algunas de ellas tenían rendimientos superiores a 2 t ha^{-1}. La mayoría de estos materiales de sorgo, con alto potencial de rendimiento y tolerancia a suelos ácidos, provenían de Uganda y Kenya, y fueron clasificados como Caudatum. De acuerdo al comportamiento de estos materiales genéticos en ensayos de rendimiento, así como al resultado de otras investigaciones tres tipos de sabanas de suelos ácidos fueron identificados: Clase 1, con 0-35% de saturación de Al 3+; Clase 2, con 36-60% de saturación de Al^{3+}; y Clase 3, con 61-90% de saturación de Al^{3+}. También se produjo material mejorado a partir de cruzamientos entre genotipos adaptados a suelos ácidos, líneas elite y nuevas fuentes de tolerancia al Al^{3+}. Un grupo de materiales segregantes fue enviado de INTSORMIL para su evaluación en Colombia.

Luego de ocho años de trabajo colaborativo con INTSORMIL, se liberaron dos líneas: Sorghica Real 60 (MN4508) y Sorghica Real 40 (156-P5 Serere-1). Estas líneas se adaptan especialmente a niveles de saturación de Al^{3+} de 40-60% y 20-40%, respectivamente. Dos años más tarde una tercera línea, IS3071, fue liberada con el nombre de Icaraván-1. Este material se adapta a saturación de aluminio del 40 al 60%. Además de su tolerancia a distintos niveles de Al 3+, estos materiales son altamente tolerantes a enfermedades de la panoja, alcanzan mayores rendimientos en la estación lluviosa, y los granos tienen menos de 1% de polifenoles, cuando analizados por el método de Foi y Dennis.

Debido a su baja rentabilidad en Colombia, el área cultivada con sorgo ha disminuido dramáticamente desde 1995. Sin embargo, recientemente, se ha despertado un interés creciente por el desarrollo de sorgo y millo perla para una producción de forraje que permita mantener la producción ganadera durante los períodos sin lluvias, así como cultivos de cobertura. También se busca reducir sistemas de producción que roturan el suelo, los que están siendo utilizados crecientemente en el Piedemonte Llanero.

1. Investigator, CORPOCIA C. I. La Libertad, Villavicencio, A.A 3129, Colombia

In order to incorporate nearly 2 million hectares of acid soils of the Eastern Plains into agricultural production systems, ICA (Colombian Agriculture Institute) developed a collaborative sorghum breeding program with INTSORMIL in 1983. The main objective was to establish a regional program for the development of grain sorghum varieties and hybrids with tolerance to at least 60% of Al^{3+} saturation in soils. After evaluating about 6000 sorghum genotypes from the world collection at CIAT, Quilichao and ICA, Villavicencio (now CORPOICA), it was found that only 8% of the lines were able to grow well in soils with A13+ saturation above 50%, and some of them had a yield higher than 2.0 t ha^{-1} (Table 1).

Most of the high yielding and Al^{3+}-tolerant genotypes from the world collection came from Uganda and Kenya were classified as Caudatums. Since the concept of Al^{3+} saturation levels was developed, three classes of Al^{3+} saturation were selected according to the performance of genetic material in yield trials and other related research. Acid-soil savannas were classified into three groups, Class 1 (0-35% Al^{3+} saturation), Class 2 (36-60% Al^{3+} saturation) and Class 3 (61-90% Al^{3+} saturation). This new approach is significant because it indicates not only the level of Al^{3+} saturation at which a variety can produce economically viable grain yields, but also the agronomic management suitable for that line at a particular level of Al^{3+} saturation. Table 2 indicates the performance of some sorghum lines at each level of Al^{3+} saturation. Breeding material was also generated from crosses among Al^{3+}-tolerant sources, IS 8577, IS 7173, IS 8931, IS 3071, IS 6944, IS 9084 and MN 4508, and agronomically elite U.S. lines, MS SUD1, Tx623, Tx430, and NB 9040. A different set of segregating material was sent from INTSORMIL for screening in Colombia.

After 8 years of collaborative work with INTSORMIL, two lines that originated from the world collection, MN 4508 (Sorghica Real 60) and 156-P5 Serere-1 (Sorghica Real 40) were released for use in Al^{3+} saturation levels of 40 to 60% and 20 to 40%, respectively. Two years later, a third line IS 3071 (ICARAVAN-1) was released for Al^{3+} saturation levels of 40 to 60%. Besides having Al^{3+} tolerance, these three genotypes were highly tolerant to head diseases, yielded better in the rainy season and had less than 1% of various polyphenols. In 1997, ICA breeders selected the lines SBL-107 from a cross between MN 4508 and TX-430 that performed well in soils with 40 to 60% of Al^{3+} saturation.

Due to the low profitability of grain sorghum in Colombia, the production area for sorghum has decreased dramatically since 1995. Recently, there has been an increased interest in development of sorghum and pearl millet cultivars for forage during the dry season and also as cover crops for the zero-tillage production systems in the Eastern Piedmont Plains.

Table 1. Grain production (t ha^{1}) and plant height (cm) of sorghum genotypes grown in soils with 50% Al^{3+} saturation, Colombia.

Genotype	Plant height (cm)	Grain yield (t ha^{1}), semester A and B	
		A	B
MN 4508 .	182	3.2	3.0
Serere -1	162	3.3	2.8
IS 3071	190	2.8	2.4
IS 8577	187	3.3	2.8
5 DX	178	2.4	2.1
ICA - Nataima	96	0.5	0.9

Table 2. Grain production (t ha^{1}) of sorghum genotypes grown under three levels of Al^{3+} saturation, Colombia.

	Grain yield (t ha^{1}) Al^{3+} levels		
Genotype	31%	60%	90%
MN 4508	3.4	1.6	1.0
Serere -1	3.6	1.6	1.0
IS 3071	3.8	1.5	0.8
IS 8577	4.1	1.7	1.1
5 DX	2.7	1.4	1.5
ICA - Nataima	3.6	1.3	0.9

Efficiency of Two Rapid Screening Methods for Aluminum Tolerance in Soybean *(Glycine max(L.)* Merril) Genotypes

Ruben Alfredo Valencia[1], Margarita Rosa Gomez[1], and T.R Bueno[1]

Resumen

*La toxicidad por aluminio es uno de los factores limitantes para el desarrollo sostenible de regiones del mundo con suelos ácidos. La selección de genotipos con adaptación específica a estos agro-ecosistemas es la estrategia más viable dentro del presente contexto. Para evaluar la eficiencia de métodos rápidos de evaluación para la tolerancia al aluminio en soya (*Glycine max *(L.) Merril), se compararon dos metodologías: la tinción por hematoxilina (MTH) y la recuperación de raíces (MRR). Se evaluaron cinco genotipos, los que crecieron en solución nutritiva (modificación de Alva et al. 1986) con diferentes niveles de aluminio: 0, 100, 150, 160, 170 y 180 M. La evaluación se realizó bajo condiciones controladas de luz, temperatura y humedad relativa. El pH de la solución se ajustó a 4.2 + 0.1. Los genotipos se habían clasificado como sensibles, intermedios y tolerantes al aluminio, de acuerdo a su respuesta en evaluaciones de campo.*

Aunque la tinción con hematoxilina varió entre los distintos genotipos, no se observó una buena correlación entre esta variable y la tolerancia al aluminio. Por otra parte, la habilidad de las plantas a recuperarse del estrés por aluminio, se redujo cuando las concentraciones de Al^{3+} se aumentaron, y con respuestas muy contrastantes entre los genotipos. Por ejemplo, los materiales sensibles, cuando fueron crecidos en 160 M de aluminio, no se recuperaron, evento que sí sucedió con las variedades tolerantes. En secciones transversales de tejido de raíz de la variedad Soyica P-34 (sensible), se observaron paredes celulares destruidas, plasmólisis celular, espacios intercelulares anormales, así como una reducción en el número de células en el tejido parenquimático. El genotipo tolerante Lissa 09, por su parte, mostró paredes celulares engrosadas, células binucleadas, núcleos rodeados por numerosos amiloplastos y un gran número de células parenquimatosas. La recuperación del crecimiento radical, mostró una correlación positiva con biomasa seca de plántulas en el campo. Por lo tanto, esta técnica sería una buena alternativa para la evaluación temprana de genotipos para su tolerancia a suelos ácidos.

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Aluminum toxicity is a limiting factor for the sustainable development of acid soils of the world. The selection of genotypes with specific adaptation to this agroecosystem is the most viable strategy. In order to evaluate the efficiency of a rapid screening method for aluminum(Al^{3+}) tolerance in soybean *[Glycine max* (L.) Merril), two methodologies were compared: The stain hematoxylin method (Stain Length) and the root-recovery method (RRM). Five genotypes were evaluated in a nutrient solution (Table 1) with six levels of aluminum (0, 100, 150, 160, 170 and 180 (M), under controlled conditions of light, temperature and relative humidity. Genotypes were categorized into Al^{3+}-sensitive, intermediate Al^{3+} -Molerant, and Al^{3+}-tolerant according to their visual response and yield performance under field conditions (Table 2).

Although the length of root staining with hematoxylin was different among genotypes,was not related to the genotype's tolerance or sensitivity to aluminum (Table 3). On the other hand, the plant's ability to recover from the Al^{3+}-stress was reduced on increasing the Al^{3+} concentration, with contrasting effects among genotypes. In contrast to Al^{3+}-tolerant genotypes, Al^{3+}-sensitive genotypes grown at an Al^{3+}level of 160 (M did not show root recovery (Table 2). In transverse sections of root tissues of the soybean variety Soyica P-34 (Al^{3+}-sensitive), degenerated cell walls, cellular plasmolysis, abnormal intercellular spaces and a reduced number of cells in the cortical parenchyma were observed. The Al^{3+}- tolerant genotype, Lissa 09 showed thick cell walls, binuclear cells, nucleus surrounded by many amyloplasts and a high number of parenchyma cells. The recovery of root growth showed a positive correlation with the shoot dry mass measured in the field. Therefore, the technique provides a good alternative to screening genotypes for tolerance to acid soils.

References

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Table 1. Nutrient solution composition for soybean.

Nutrient	Stock solution			Nutrient solution used		Final nutrient solution composition		
	g/L	mm	ml/L	Cations	Anions	Nutrient	mg/L	mM
$Ca(NO_3)_2$ $4H_2O$	63.76	270.00	5.00	Ca:54.1	NO_3-N:37.817	Ca	54.1	1349.8
$NH4NO_3$	1.60	20.00		NH4-H:1.4	NO_3-N:1.400	NH4-N	1.409	9.95
KNO_3	5.05	50.00		K:9.784	$NO_3N:_3.505$	K	10,175	260,218
$Mg(NO_3)_2$ $6H_2O$	5.13	20.00	5.00	Mg:2.431	NO3-N:2.802	Mg	2,431	99,992
						NO3-N	45,524	3,250
KH_2PO_4	1.36	10.00	1.00	K:0.391	P:0.309			0,089
$FeSO_4$ $7H_2O$	2.75	9.89		Fe:2.719	S:1.091	Fe	2,719	48,686
						S1	0,964	49,646
EDTA	3.72	12.70	5.00		EDTA:18.6	EDTA	18.6	67,246
$MnCl_24$ H_2O	0.4	2.00		Mn:0.0555	Cl:0.0716	Mn	0.0555	1.01
						Cl	0.0716	2,019
H_3BO_3	0.37	6.0	0.5		B:0.324			
$ZnSO_4$ $7H_2O$	0.575	2.00		Zn:0.065	S:0.0022	Zn	0.0654	1,000
$CuSO_4$ $5H_2O$	0.05	0.20		Cu:0.0063	S:0.0022	Cu	0.0064	0.100
$Na2MO_4$	0.484	2.00		Na:0.0454	Mo:0.096	Mo	0.096	1,000

The pH of the solution was adjusted between 4.2 + 0.1. Soybean lines were also evaluated in acid-soil conditions to measure the efficiency of the proposed screening technique.

Source : Alva et al. 1988

Table 2. Critical levels of Al^{3+} toxicity* and visual response to Al^{3+} of soybean genotypes.

Genotype	Al critical level (M) *	Visual rating
Linea Lissa 09	220	Al^{3+}-tolerant
Soyica Altillanura 2	220	AP^{3+}-tolerant
Soyica Ariari 1	180	Intermediate
Soyica P-34	170	Al^{3+}-sensitive
Soyica P-33	160	Al^{3}+-sensitive

*** Al^{3+} critical level: No root growth recovery after transplanting to a medium without Al^{3+}.**

Table 3. Comparison of root stain length and root recovery of soybean genotypes grown in a nutrient solution with 160 mM of Al^{3+}, with dry matter production of these genotypes under field conditions.

Genotype	Stain length (cm)	Relative dry matter[1] (51 DAS)[2]	Root recovery (cm)
Linea Lissa 09	0.90	1.18	0.20
Soyica Altillanura 2	0.70	0.88	0.20
Soyica Ariari 1	0.80	0.70	0.10
Soyica P-33	0.70	0.64	0.0
Soyica P-34	0.70	0.67	0.0

1. Relative dry matter: dry matter production at 300 kg ha-1 of dolomite lime/dry matter production at 2000 kg ha-1 of dolomite lime.
2. DAS: days after sowing.

Prospects for Sorghum and Pearl Millet Utilization in Acid Soils in Cauca State

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Resumen

Durante el segundo semestre de 1998, tres ensayos de la Red Latino Americana de sorgo y millo perla, fueron conducidos en la finca "El Nilo" en el departamento del Cauca. Los ensayos hacen parte del proyecto adelantado por la Asociación de Cabildos Indígenas del Norte del Cauca (ACIN), el Programa Nacional de Transferencia de Tecnología (PRONATTA), el Ministerio de Agricultura y el Proyecto de Antropología Agrícola del CIAT. El proyecto busca mejorar el estilo de vida de la región a través de la diversificación de los sistemas agrícolas, la identificación y solución de los problemas presentados en la selección de los cultivos adaptados y el mejoramiento de los sistemas actualmente utilizados por las comunidades indígenas y negras de la región, bajo un proceso de investigación participativa.

Dos ensayos consistentes en 20 líneas B (Mantenedores de la esterilidad) y 15 líneas forrajeras (sorgo y millo perla) fueron sembradas el 9 de Septiembre bajo un diseño de bloques completos al azar. El desempeño de las líneas de sorgo provenientes de ICRISAT fue considerablemente inferior al mostrado por el testigo utilizado (REAL 60). Así mismo, IS 31496 y IS 13868, mostraron ser los mejores materiales de sorgo forrajero con un gran potencial de utilización en la región. Los diferentes materiales de millo perla utilizados representan una gran alternativa como forraje, no obstante, su imposibilidad de producir suficiente cantidad de semilla para el mantenimiento entre los agricultores, puede representar un obstáculo para su utilización.

Background

A collaborative project was started in 1998 involving the Indigenous Town Council Association of Northern Cauca (AON), the National Program for Transfer of Technology (PRONATTA), and the Anthropologic Agriculture Project at OAT, and other NGOs, The main objective of the project is to develop productive systems with appropriate and sustainable technologies within the participative research framework, which enhance the lives of the indigenous and black communities in northern Cauca state.

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The specific objectives of the project are:

i. To identify the problems and evolve solutions for the selected crops through participatory research activities involving producers from different communities,

ii. To study and improve the agricultural systems used in the plains by different indigenous and black communities in the northern Cauca department; to develop new productive systems with adequate and sustainable technologies through participatory research with the communities and producers.

Vast areas, commonly used for cattle ranching (19 000 ha), represent a high agricultural potential for these communities. Currently, 6000 ha have been recovered for the indigenous communities, which could be used for crop production.

The potential end users of the project results are small farmers belonging to the Corinto Reservation (11 120 people from 2 471 families), Huellas Reservation (7 264 people from 1482 families), Toez Reservation (817 people from 136 families), and the Pilamo and La Arrobleda black communities.

The Indigenous Town Council Association of Northern Cauca (ACIN) proposed to produce different kinds of food and to commercialize their products within the zone. The ultimate objective was to improve the lives of people of the region.

The project is currently located at the Center of Alternative Agricultural Research "El Nilo" farm, where research and training programs have been conducted since May 1998, with the help of two technicians and personnel from CIAT's agricultural anthropology program. At the same time, the Research Center of Community Services (CISEC, in Spain), with Santander of Quilichao, is taking the lead in working on the hillside with indigenous communities.

The Cassava, Beans and Rice Programs from CIAT have been working in the region in order to select adapted varieties. During the second semester of 1998, the ICRISAT/CIAT Sorghum Project conducted two trials at the "El Nilo" farm.

Network trials at "El Nilo" farm, Caloto, Cauca (CIAT)

A complete set of materials including sorghum and pearl millet (B, R and Forage lines), were dispatched to the Center of Alternative Agricultural Research " El Nilo" in the Cauca Department, through Dr. German Escobar (Anthropologic Agriculture Project in CIAT). The center is part of a project conducted by the Indigenous Town Council Association of Northern Cauca (ACIN) and the National Program for Transfer of Technology (PRONATTA), with the collaboration of CIAT and other NGOs.

Soils and management

Geologically, the soil at the center originates from early sedimentary and intrusive volcanic rocks, resulting in red and yellow clay. The experimental center is situated in the alluvial poorly drained hills of Puerto Tejada. The soil is classified as Oxic Dystropept. The field was fallow with native grasses: Land preparation was initiated with a systemic herbicide (glyphosate, 3.0 1 ha^{1}) application. Fifteen days later, all residues were incorporated with 2 passes of a rototiller plough. Seedbed, furrows and ridges at 10 cm depth and 60 cm apart were prepared by hand.

At planting time, 100 kg ha^{1} of ammonium sulfate, 120 kg ha^{-1} triple super phosphate and 100 kg ha^{-1} KCI were applied. Atrazine spray (1.51 ha^{1}) was applied immediately after planting. Subsequent weed control was done by hand during crop development.

Results

Two trials consisted of 20 B lines and two checks (Real 60 and SPRU 94008); and 15 forage lines of sorghum and pearl millet and one check (Sikuani maize), respectively, were planted on 9 Sept in a completely randomized block design. The R-lines set could not be planted due to insufficient area.

a. Maintainors (B-lines) trial

Performance of the selected entries is given in Table 1. The scale of selection at Caloto was moved up to 3.7 due to the differences in field variation in management. Entries showing a delay in flowering were rejected. Real 60 showed the best agronomic performance. However it was more susceptible to leaf diseases than ICRISAT-bred selections (Table 1). The high CV values showed the ample variation in the field, especially during crop establishment.

b. Forage sorghum and pearl millet trial

Basically, tiller number and high grain production were important factors in the selection of the materials. In addition, agronomic score and leaf diseases score were also included. Agronomic performance and the other characteristics of the selected entries are given in Table 2. IS 31496 and IS 13868 represented the best sorghum forage entries, and could be used for grain or forage in this zone.

Weather conditions influence seed-setting rates in pearl millet entries and only the selected entries produced an adequate amount of seed. Other entries did not set seeds due to the high moisture conditions. For future trials, date of planting and field management should be modified to facilitate the selection of well-adapted materials.

Table 1. Performance of selected grain sorghum B-lines at Caloto, Colombia, 1998-II.

Plot	Pedigree	No of plants	Plant height (m)	Green leaf area (score)[1]	Agronomic performance (score)[2]	Diseases (score)[3]
1614	SPA_2 94013	30.7	1.3	1.7	2.3	2.7
1251	SPMD 94019	13.3	1.5	1.3	2.7	1.7
1617	SPA_2 94016	37.0	1.1	1.3	3.0	2.3
1142	ICSB 73	20.0	1.2	1.0	3.3	1.7
1152	ICSB 89	19.7	1.2	1.0	3.3	1.3
1156	ICSB 94	15.3	1.3	1.3	3.3	1.7
1234	SPMD 94004	23.3	1.1	1.3	3.3	2.0
1236	SPMD 94006	22.7	1.1	1.3	3.3	1.7
1275	SPMD 94045	12.3	1.1	1.0	3.3	1.3
1623	SPA_2 94021	13.7	1.2	1.3	3.3	1.0
1632	SPA_2 94029	30.0	1.3	1.0	3.7	1.7
	Controls					
1	Real 60	40.0	1.6	1.8	1.6	3.0
5	SPRU 94008	18.0	1.0	1.8	3.3	2.5
Trial mean		18.48	1.2	1.26	3.34	1.71
SE±		8.65	0.14	0.26	0.66	0.56
CV%		59.92	17.67	38.22	24.75	43.5

1. Scale 1 to 5, where 1 = maximum green leaf area and 5 = least green leaf area
2. Scale 1 to 5, where 1 = most desirable and 5 = least desirable
3. Scale 1 to 9, where 1 = free of leaf diseases, 2 = 1 -5% of leaf area affected, 3 = 6-10%, 4 = 11 -20%, 5 = 21 -30%, 6 = 31 -40%, 7 = 41 -50%, 8 = 51 -75%,and 9 = > 75% of leaf area affected.

Table 2: Performance of selected forage sorghum and pearl millet materials at Caloto, Colombia, 1998-II.

Plot	Pedigree	No of plants	No of tillers	Plant height (m)	Green leaf area (score)[1]	Agronomic performance (score)[2]	Diseases (score)[3]
	Sorghum						
879	IS 31496	31.0	4.0	1.8	1.0	1.0	1.7
897	IS 13868	26.3	2.7	2.0	1.3	1.3	1.0
	Pearl millet						
30	TGP	26.3	6.0	1.9	2.0	1.3	2.3
29	LHGP	20.7	6.0	1.8	1.7	1.7	1.3
3	ICMV 87001	26.3	6.0	1.8	2.0	1.7	1.3
8	ICMP 89410	23.7	8.7	1.8	2.0	1.7	2.0
15	ICMV 85404	17.3	9.3	1.6	1.7	2.0	1.0
19	ICMV 93751	22.7	5.3	1.8	2.3	2.0	1.3
20	ICMV-IS 85321	24.3	5.3	1.8	2.0	2.0	1.3
28	SOSAT-C-28	23.7	5.7	1.7	2.0	2.0	2.0
	Control						
1	Sikuani	4.0	0.0	1.6	2.0	4.5	2.0
Trial mean		23.3	4.9	1.8	1.8	2.0	1.6
SE±		6.4	2.3	0.1	0.4	0.8	0.4
CV%		26.1	39.1	10.4	34.8	35.1	41.9

1. Scale 1 to 5, where 1 = maximum green leaf area and 5 = least green leaf area
2. Scale 1 to 5, where 1 = most desirable and 5 = least desirable
3. Scale 1 to 9, where 1 = free of leaf diseases, 2 = 1 -5% of leaf area affected, 3= 6-10%, 4 = 11 -20%,5 = 21 -30%, 6 = 31-40%, 7 = 41-50%, 8 = 51-75%, and 9 = > 75% of leafarea affected.

Report on Acid-Soil Tolerant Sorghum Performance in the Intermediate Savannas of Guyana

C. Paul[1], H. Adams[1], and C. Wickham[1]

Resumen

Las Sabanas Intermedias del Trópico Húmedo en Guyana representan una amplía zona con un alto potencial agrícola. Son principalmente utilizadas en ganadería extensiva basada en el pastoreo de gramíneas nativas, caracterizadas por su bajo nivel nutritivo y baja productividad. Los suelos de las sabanas Intermedias son de carácter ácido, debido a sus altos contenidos de Al intercambiable, poseen bajos contenidos de nutrientes y presentan un alto potencial de erosión.

Las actividades agrícolas en las Sabanas Intermedias se inicio desde la década de los cuarenta con la utilización de diversos cultivos y la introducción de pasturas mejoradas para la producción de leche. Cultivos como maíz, sorgo, soya y algodón entre otros han sido utilizados, bajo la dirección del Instituto de Desarrollo e Investigación Agrícola del Caribe (CARDI). Instituto encargado del desarrollo de tecnologías innovadoras, apropiadas y aparentemente sostenibles para integrar cultivos y ganadería en los sistemas de producción.

A nivel de sorgo, la variedad de sorgo 3D originaria de Uganda fue introducida a Guyana desde Brasil (EMBRAPA). Es una accesión de floración tardía, alta y de nervadura verde clara, después de la maduración conserva su follaje verde por lo cual puede ser utilizada como doble propósito. Posee tolerancia a hongos de la panoja y mancha blanca. Su producción media es de 4.3 toneladas por hectárea.

Introduction

The tropical humid Intermediate Savannas (IS) of Guyana are located some 160 km behind the Adantic Coastal strip and occupy a landmass of approximately 270 000 ha. Of this, only about 80 000 ha are true savanna. These include close to 59 000 ha of acid sandy loam soils with reasonably good agricultural potential. However, these soils represent a fragile ecosystem that requires careful and expert management for the successful and sustainable production of crops and improved pastures.

Native grasses of the IS have very low nutritive value and productivity, leading to poor body weight gain of cattle, low stocking rates and requiring as much as 5-8 years to prepare beef herd for the market. Apart from the inherent soil problems associated with high acidity due to Al^{3+} saturation, low nutrient content, high erosion potential, low moisture retention capacity, vulnerability to compaction (especially in the Ultisols), and lack of irrigation, are the problems of developing cultivars tolerant to prevailing soil conditions. Also, there are problems with the availability and utilization of inputs like labour and materials that are cost efficient, developing a viable infrastructure, providing marketing and credit facilities, and developing appropriate, low-cost, competitive, and sustainable technologies.

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Agricultural activities that began in the IS during the 1940s have led to successes as well as failures. These activities involved beef and dairy enterprises as well as the production of annual crops including maize *(Zea mays),* sorghum *(Sorghum bicolor),* cowpea *(Vigna stnensis),* soybean (*Glycine max),* cotton *(Gossypium barbadense)* and groundnut *(Arachis hypogea).* Lately, the Caribbean Agricultural Research and Development Institute (CARDI) has developed innovative, appropriate and apparently sustainable technologies for integrated crop and livestock production using a systems approach.

Topography

The savannas are gently undulating to flat plains with slopes of 1 to 8 % and with altitudes from 6 to 10 m above sea level in the north to about 70 to 100 m above sea level in the southwest. Many creeks and rivers, forming a regular dendritic drainage pattern, dissect the plains. Because of the well-drained sandy soil the majority of the smaller creek beds are dry except after rains. Gullies vary from shallow to 10-15 m deep. The flat base of the deep gullies consists of a narrow strip of swamp or marshland on either side of the creeks.

Abandoned concrete-like nests that sometimes rise up to 2 m above the ground manifest previous termite activity; these can disrupt land-clearing operations.

Climate

The climate of the Intermediate Savannas has been described as tropical wet and dry. The mean annual rainfall is 2250 mm with a bimodal distribution pattern that allows the cultivation of two rainfed annual crops per year during April-August and November-January. The longer wet season experiences 40 to 60% of the rainfall and the shorter season about 16%. The frequent high rainfall intensities cause sheet, rill and gully erosion that commences with surprising speed in places where the natural vegetation is disturbed. The high variability, intensity and erratic distribution of the monthly rainfall are constraints to agriculture.

The mean annual temperature is 26 °C with a maximum diurnal fluctuation of 10°C. The relative humidity is high in the early mornings (>90%) with a minimum of 65% in the early afternoons. Average daily sunshine varies from 5 to 8 hours and cloud cover is pronounced during the rainy seasons; this causes a problem for late-maturing varieties of sorghum.

The average annual pan evaporation is 1830 mm with periods of soil-moisture deficit in February and September to November.

Soils

The soils of the IS consist of sub continental and old delta deposits, sands and clays with occurrences of Bauxite, Laterite and Kaolinitic clay. White quartz sand (white sands) with brown loamy and sandy clay (brown sands) sediments irregularly dispersed characterize the surface layer. Thirty-eight soil types have been identified; they range in texture from coarse sands to medium-sandy clays. The white sands are classified as Entisols and the brown sands as Ultisols and Oxisols.

The most extensively occurring soil types are the Ebini sandy loam, the Kasarama loamy sand, the Bukarama loamy sand, the Tabela sand and the very infertile Tiwiwid white sand which occurs in small pockets. It has been recommended that the Tiwiwid sand not be disturbed but left under its native vegetation as it erodes easily when exposed.

Physically, the soils have a good structure and are well drained but they are low in clay and organic matter content. They possess low water-holding capacity and are very dry in the top layers during the dry season; clay and organic matter content is critical to their agricultural potential. Tillage improves their physical condition but they crust easily, have a high erosive index and lose organic matter content by oxidation very rapidly under the hot tropical climate. Crop production on the soils has been observed over the last three cycles of cropping and it is felt that the management of the soils must be linked to increasing the level of organic matter by addition of crop residues and/or animal manure. This would serve to bind and retain clay particles and added nutrients within the soil and thereby improve their fertility and structure.

Chemically, the soils are acidic (pH 4.3 to 5.9) with Al^{3+} dominating the cation exchange complex. As a result, applied P fertilizer, considered to be the most limiting nutrient element in the soils, is rapidly fixed. Soil acidity, especially in the subsoil, has been identified as a major limitation to root development.

For most crops, N, P, K, Ca, and Mg are all limiting, and micronutrients are also lacking. Dolomite limestone is usually applied (incorporated to a depth of 20-30 cm) at the rate of 1.5 - 21 ha^{-1} after every 3-4 crop cycles to correct soil pH as well as to add Ca and Mg.

Sorghum performance

a. Origin

The sorghum variety 3DX 5711910 (3D) which originated in Uganda, was brought in from EMBRAPA, Brazil and introduced into Guyana in 1989.

b. Description

The accession 3D matures in 110-120 days with 50% flowering in 75 days. The plant grows to 2 - 2.5 m in height, is moderately covered with waxy blooms and bears leaves with dull-green midribs. At maturity the plant remains green, thereby lending itself to ratooning. Generally, a single moderately exerted semi-open panicle is borne on the main stalk with reproductive tillers occurring only in the ratoon crop.

The panicle is aweless and bears lustrous, medium-sized (100-seed mass of 3.5 g), brownish/light red seeds semi-enclosed in purple glumes. The panicle threshes cleanly.

c. Insect and disease reaction

3D has displayed tolerance to head molds and leaf blight (*Helminthosporium* spp.). Field damage by insects pest other than mole crickets and army worms is negligible. Mild damage from the storage pest *(Sirotroga cerealella)* has been observed on the accession.

d. Yield performance

In the smaller plots of a comparative yield trial, 3D exhibited a yield potential of 4.3 t ha^{-1} In relatively larger plots, yields range from 3 to 4.5 t ha^{1} (Table 1).

Sorghum large-scale field test

The sorghum cultivar 3D was sown on a 2.4 ha plot. All operations were mechanized. This cultivar exhibited very high levels of adaptability to the Savanna conditions. The results are presented in Table 2 and Table 3.

More recent data (1995-1996) on Sorghum performance in the IS of Guyana are presented in Table 4.

During 1997-1998, the variety 3D was further evaluated in large plots in IS. The results are presented in Table 5.

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Table 1. Yield of the sorghum variety 3DX 5711910 in variety trials over four seasons in the Intermediate Savannas, Guyana, 1991-93.

Season	Yield (t ha^{1})
November/December 1991	3.58
May/June 1992	4.13
November/December 1992	4.50
November/December 1993	4.27
Mean	4.12
SE± (df = 4)	0.195
95% confidence interval	0.383

Mean of 4 replicates (SE = 44, df = 21) In a comparative yield trial

Source: CARDI1996

Table 2. Performance of sorghum (variety 3D) in a large-scale field test, Ebini, Guyana, planting season 1993.

Character	Expression
Maturity	112 days
Plant height	1.8m
Panicle type	Semi-open
Panicle exertion	Good
Tillering	Good
100-seed mass	3.5 g
Seed color	Light red
Bird resistance	Good
Foliar-disease tolerance	Good
Head-mold tolerance	Good
Grain yield	2.3 t ha^{-1}

Table 3. Performance of eight sorghum accessions in a comparative yield trial in the Intermediate Savannas on the Ebini Sandy Loam, Guyana, cropping season 1993/94.

Accession	Days to 50% flowering	Days to maturity	Plant height at maturity (cm)	Grain yield t ha^{-1}
47-MJ93	79	102	106	1.95
25-MJ93	83	103	126	2.49
9-MJ93	84	102	115	2.45
15-MJ93	66	104	151	2.86
63-MJ93	86	102	148	2.35
85 -MJ93	78	102	102	1.49
64-MJ93	87	102	157	3.34
3D	78	102	153	4.27

Table 4. Production data and net economic returns for selected crops grown in the Intermediate Savannas, Guyana, 1995-96.

Variable	Soybean	Sorghum*	Peanut	Cowpea
Yield (t ha^{-1})	2.5	3.5	1.5	1.2
Production cost ha"[1] (US$)	725	700	700	744
Net return ha^{-1} (US$)	50	140	480	108

*Sorghum variety 3D
Source: Paul et al, 1997

Table 5. Sorghum (variety 3D) performance in the Intermediate Savannas, Guyana, 1997-98.

Year	Plot size	Yield (t ha^{1})	Remarks
1997	1ha	2.1	season 1
1997	1 ha	0.9	season 2*
1998	4 ha	1.2	season 1
1998	3 ha	1.9	season 2

***Season affected by the "El Nino" phenomenon**

Session III: Latin American Sorghum and Pearl Millet Network Project

Evaluation of Sorghum and Pearl Millet for Acid-Soil Tolerance in the Oriental *Llanos* of Colombia

Belum VS. Reddy[1], Andres F. Rangel[2], Carlos A. Iglesias[3], and Jaime H. Bernal[4]

Resumen

Grandes extensiones de tierra en los países de Latino América (comúnnmente llamadas Sabanas, Llanos o Cerrados), que tradicionalmente son usados para la producción ganadera, poseen un gran potencial agrícola. Sorgo y millo perla representan una alta contribución dentro de los programas de diversificación de dichos sistemas. Gran cantidad de materiales de sorgo granífero (materiales andro-estériles, restauradores de fertilidad) y materiales forrajeros de sorgo y millo perla fueron introducidos en Colombia.

Durante cuatro ciclos consecutivos los materiales fueron evaluados en diferentes porcentajes de saturación de Al^{3+} intercambiable del suelo. Sorgos andro-esteriles y restauradores de fertilidad de alta producción de grano y líneas forrajers de sorgo y millo perla fueron seleccionados por su tolerancia a suelos ácidos, y sus producciones de grano/forraje se compararon con variedades liberadas por INTSORMIL (para grano) y maíz Sikuani (para forraje). Las líneas finalmente seleccionadas: 20 pares de líneas A/B; 20 líneas restauradoras de fertilidad, 4 materiales de sorgo y 20 de millo perla, son mantenidos dentro de un programa de multiplicación de semilla. Así mismo, se menciona brevemente el desarrollo de híbridos y su selección. Se formaron dos pablaciones de sorgo en dos poblaciones y sus derivados, e inclusive se realizaron ensayos de emasculación, los cuales hacen parte de los materiales mejorados para evaluación y observación de los próximos ciclos de selección para tolerancia a suelos ácidos.

Introduction

Nearly 23% of the soils in the tropics are Oxisols. About 60% of these soils (about 500 million hectares) are in the tropical Americas. The acid, infertile Oxisols areas (71 million ha) in tropical America are dominated by the savanna system in the *Llanos* of Colombia and Venezuela and the *Cerrados* of Brazil (Gourley, 1983). These areas are traditionally used for extensive livestock production. Ten hectares of native grass pasture are needed to raise one animal. Research at the International

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Center for Tropical Agriculture (CIAT) has contributed to the replacement of native grasses by *Brachiaria* species and this has helped to increase the productivity of the savanna 10-fold (Raul Vera, 1997, personal communication). There is a growing awareness of the need to diversify the agropastoral systems. CIAT is experimenting with upland rice, mixed systems with a legume and *Brachiaria* species, maize, etc. Further, sorghum and pearl millet are considered to have the potential to contribute to sustainable agropastoral systems. Plant breeders have traditionally concentrated their work in sorghum and pearl millet in neutral and high-input conditions. However, the International Sorghum and Millet (INTSORMIL) Program identified 20 high-yielding, acid-soil-tolerant sorghum lines (Gourley, 1983: and Gourley, 1991)[1] by screening the materials both in the glass house and under field conditions. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) developed over the years high-yielding breeding materials (A/B-lines, R-lines, and populations) in sorghum and pearl millet in a range of height, maturity, and plant and grain color. They provide variable diversity for identifying high-yielding materials for acid-soil conditions.

ICRISAT, CIAT and National Programs (Colombia, Brazil, Venezuela and Honduras) in the region are therefore jointly implementing the Inter-American Development Bank (IDB)-funded project for developing acid-soil-tolerant sorghum and pearl millet lines from 1996 onwards. The purpose of this paper is to briefly describe the introductions from ICRISAT and to summarize the results obtained from screening these materials under acid-soil conditions.

Materials and Methods

ICRISAT programs at Patancheru, India and at Bamako, Mali developed a diversified array of sorghum and pearl millet male-sterile lines, restorer lines, and populations. The sorghum program followed a trait-based breeding approach while improving the materials for specific constraints, grain yield and adaptation, while the pearl millet program targeted the improvement for grain yield and resistance to downy mildew at ICRISAT. The resulting materials—diverse sets of 378 pairs of A/B grain sorghum lines, 784 grain sorghum restorer lines/varieties, 94 forage sorghum lines, 10 pairs of pearl millet A/B-lines, 30 pearl millet populations, and 21 pearl millet pollinator lines-were introduced into Colombia in October 1995 from ICRISAT. In addition ms_3-based large-grain (ICSP LG), maintainer (ICSP B) and high-tillering (ICSP HT) sorghum populations were introduced from ICRISAT, Patancheru, India. Among the grain sorghum R-lines, 101 lines were introduced from ICRISAT, Bamako, Mali and the rest were from ICRISAT, Patancheru, India. The CIAT farm at Cali was utilized[2] for seed increase and for assessing the entries for resistance to leaf diseases (leaf blight, anthracnose, rust, maize dwarf mosaic, and sugarcane mosaic viruses). Also, selection for agronomic desirability and high grain yield (in the case of grain sorghum), and high biomass (in the case of pearl millet and forage sorghums) were

1. Primarily from the introductions made from the United States Development Agency(USDA),Meridian,Mississippi sorghum collection, and the Empresa Brasileira de Pesquisa Agropecuaria (EMBRARA) Al^{3+}- tolerance breeding program during the early 80s

2. December 1995-May 1996, February-June 1997, and February-June 1998

carried out in the first year of multiplication (Dec 95-May 97). Selections obtained from 1995-96 (Cali, evaluations) for acid-soil tolerance (Al^{3+} toxicity, and low-base saturation) were screened during the 1996 semester I (June-September 96) at Santader de Quilichao (Cauca) and La Libertad (Villavicencio, Meta). The resulting selections were further evaluated at Quilichao, La Libertad, and Carimagua (Meta) during 1996 semester II (Sep 96-Jan 97). The selections thus obtained were tested further for acid-soil tolerance at Matazul farm (Meta) during 1997 semester II. Further, 97 hybrids developed from the selected 26 A-lines and five ICRISAT R-lines and three INTSORMIL R lines were evaluated at Matazul in 1997 semester II. The selected hybrids were seed-increased during the 1998 semester I at CIAT, Palmira (Valle del Cauca)

The soils at CIAT, Cali were close to neutral (pH 7.5) with high organic matter (4.7%), high P, Ca, Mg, and K contents, and low in B, Zn, and S. Also, Al^{3+} saturation was very low. At Quilichao, the soils are acidic (pH between 3.9 to 4.67) with Al^{3+} saturation ranging between 36-55%. The soil organic matter is high (6.65 to 8.80 %) with moderate contents of P, and K, and very high in Mg, and low in B. The soils at La Libertad are also acidic (pH 4.84) with *66%* of Al^{3+} saturation, low organic matter concentration (2.0%), high in P contents and low in K, Mg, and B. Soils at Carimagua are also acidic (pH 4.2) with a high Al^{3+} saturation (71%), moderate to high levels of organic matter (3.40%), moderate in P, low in K, Mg, and B. Native soils at Matazul, are also acidic with pH 4.1, 86% Al^{3+} saturation, moderate levels of soil organic matter (3.15%) and P concentrations, and low K, Mg and B contents.

The observations recorded were: early vigor on a 1 to 5 scale (1 = more vigorous, 5 = less vigorous); days to 50% of flowering; plant height (m) at maturity; diseases score on 1 to 9 scale (1 = free of leaf diseases, 2 = 1-5% of leaf area affected, 3 = 6-10%, 4 = 11-20%, 5 = 21-30, 6 = 31-40%, 7 = 41-50%, 8 = 51-75%, and 9 = >75% of leaf area affected) for leaf blight, anthracnose or rust; maize dwarf/garcane mosaic virus incidence on a 1 to 5 scale (1= low incidence, 5= high incidence); agronomic desirability at maturity (1 = more desirable, 5 = least desirable); grain weight (in grain sorghums); biomass (in forage sorghum and pearl millet materials); and recovery score on a 1 to 5 scale (1 = high recovery, 5 = less recovery) after the first cut in forage sorghum and pearl millet materials.

Results and Discussion

The details of the materials introduced, and the screening results were reported through six reports (ICRISAT, NARS and CIAT 1996a, 1996b, 1997a, 1997b, 1998a, and 1998b). Some of these results have been summarized by Reddy et al. (1998).

a. Grain sorghum A/B-lines

The grain sorghum (378 in all) B-lines and male-sterile lines when subjected to evaluation (resistance to leaf diseases and grain yield) at OAT, Palmira during December 95-May 96 resulted in 228 selections. An acid-soil tolerance evaluation (based on early vigor, resistance to leaf diseases, agronomic desirability and green leaf area at maturity) under Quilichao and La Libertad conditions resulted in selection of 61 and 41 B-lines, respectively. Of these, four lines were selected across the locations. Further evaluations (87 lines) at Quilichao, La Libertad, and Carimagua during the second semester of 1997 resulted in 19 lines at Quilichao, 22 lines at La Libertad, and 19 lines at Carimagua with 18 lines selected across the locations. From these, 29 lines were tested at Matazul during the second semester of 1997 and 15 were selected. The grain yield data collected on the selected B-lines from Carimagua (1996 semester II) and Matazul (1997 semester II) are presented in Table 1. The grain yield for the selected B-lines during 1996-11 ranged from 1.4 to 4.0 t ha$^{'1}$ at Carimagua with Real 60, the acid-soil-tolerant control yielding 2.9 (SD ± 0.8) t ha^{-1}. The grain yield for the selected B-lines at during 1997-11 at Matazul ranged from 1.0 to 2.7 t ha^{1} with Real 60, the tolerant control yielding 2.2 (SD ± 0.7) t ha^{-1}. Thus, the selected entries common across the locations are: ICSB 38, ICSB 88015, ICSB 89002, ICSB 89004, SPMD 94004, SPMD 94006, SPMD 94019, SPMD 93036, SPMD 94045, SPAN 94046, SPA_2 94013, SPA_2 94021, SPA_2 94022, SPA_2 94029, and SPA_2 94039. Of these, A and B lines that did not match for their height or days to flowering in ICSB 88015, SPMD 94004, SPMD 94006 and, SPAN 94046 were re-examined at CIAT, Cali during the second semester of 1998. The ICSB, SPAN, and SPMD lines were bred at ICRISAT, Patancheru, for high grain yield, resistance to anthracnose and for resistance to midge, respectively. All these are with A_1 male-sterile cytoplasm, while SPA_2s lines, were bred for high grain yield with A_2 male-sterile cytoplasm. These A/B-lines selected for acid-soil-tolerance also differed in days to flowering and plant height. However, most of these are white grained. These male-sterile lines are being maintained in the program.

b. Grain sorghum R lines

Similarly, the selection among the grain sorghum restorer lines (784) at OAT, Palmira during the first semester of 1996 resulted in 275 high-yield lines resistant to leaf diseases. Further, the evaluations at Quilichao and La Libertad during the first semester of 1996, reduced them to 83 lines with 9 lines common to both the locations. Further, successive evaluations finally resulted in 20 lines being selected from Matazul. The grain yield data for these lines at Matazul (second semester of 1997) and the selected lines in the previous trials from Carimagua are given in Table 1. The range in grain yield was 1.8 to 6.0 t ha^{-1} at Carimagua with Real 60, the tolerant control yielding 2.8 (SD ± 0.8) t ha^{-1}; while it was 1.2 to 3.1t ha^{-1} with Real 60, the tolerant control yielding 2.3 (SD ± 0.6) t ha^{1}, at Matazul. They also differed in days to flowering and plant height. The lines selected across the locations were ICSR 91008, ICSR 91012, ICSR 91020-2, ICSR 93033, IS 30469-1187-2, IS 30469-1187-4, and GD 27669. All the selected R-lines (20) are being maintained in the program.

In both trials, as explained above, Real 60, a pure-line variety released by the INTSORMIL program, was used as a control to select the lines. As seen from grain yield data, some of the B lines and R lines compare favorably with Real 60, which was found to be a restorer line.

c. Forage sorghums and pearl millet lines

Fresh forage weight, tiller number, and recovery after the first cut were used as criteria for selection among the forage sorghum lines. Thirty-three forage sorghum lines were selected from this set. Further evaluation at Quilichao (first semester of 1996), resulted in 12 lines. Additional evaluations (second semester of 1997) resulted in 5 lines from Quilichao, 5 from La Libertad, and 6 from Carimagua with 3 lines selected across the locations. Forage weight data for the selected sorghum lines for Carimagua (second semester of 1996) and Matazul (second semester of 1997) are given in Table 1. For comparison of forage lines, Sudan grass (sorghum) and Sikuani (maize) were used as controls. The selected sorghum forage lines (ICSR 93024-1, ICSR 93024-2, IS 13868 and IS 31496) are being maintained in the program.

Regarding pearl millet, 68 lines (30 open-pollinated populations, 21 A/B pairs and 17 inbred pollinators) were introduced from ICRISAT, Patancheru (first semester 1996) primarily to be testing as forage. The materials were increased at Quilichao during the second semester of 1996. Of these, 13 open-pollinated lines, 4 A/B pairs, and 2 inbred pollinators were selected. Forage yield data for the selected entries (7) at Matazul during the second semester of 1997 are given in Table 1. Further evaluations at Palmira during January to May 1997, helped us select four more populations (ICMV 15-85321, SOSAT-C-28, LHGP, and TGP), bringing the total open-pollinated varieties maintained in the program to 11. In addition, four A/B pairs are also being maintained.

The selected sorghum lines, together with INTOSRMIL lines, provide the needed diversity, as they differ in their origin, maturity, and plant height. Unlike the INTSORMIL lines, the lines selected for tolerance to acid soils were derived at ICRISAT in high-yield potential background from *Caudatum* or *Caudatum* and *Durra* hybrid races, and have resistance to leaf diseases and other limiting factors. In addition, the pearl millet material, which is quite early compared to grain or forage sorghum lines, is expected to fit in different ecological regions or cropping systems (Reddy et al., 1998).

d. Sorghum hybrids

Further, the program also tested 97 experimental grain sorghum hybrids. Test hybrids were developed by crossing 5 ICRISAT-bred lines selected in the project and 3 INTSORMIL released varieties (as pollinators) with the 26 A lines selected in the program. The INTSORMIL lines, Real 60, Icaravan and SBL 107 were found to be restorers and combined well with ICSA 38, ICSA 73, ICSA 90, ICSA 93, ICSA 94, ICSA 88004, SPMD 94004A, SPMD 94036A, SPMD 94061 A, $SPA_2$94016A and SPA_2 94022A. From the selected 48 grain sorghum hybrids, 8 hybrids had in adequate quantities of seed and hence were tested in network trials during 1998.

e. ms_3-based sorghum populations

In addition, ICSP B and ICSP LG were merged as a large-grain, acid-soil-tolerant population and several S_1s/S_2s were selected under acid-soil conditions at Quilichao and Matazul and under neutral-soil conditions at CIAT, Palmira. The fourth cycle of selection is being carried out in the second semester of 1998 at Matazul. Also, ICSP HT has been advanced with mass selection for acid-soil tolerance twice, and once in the neutral fertility conditions. The fourth cycle is being carried out at Matazul during the second semester of 1998.

Backup breeding

Further, the individual selections from large-grain, acid-soil-tolerant population, and ICSP HT populations are in the S_2 stage of testing. These, together with selections from the segregating generations of the emasculated F_1S made between ICRISAT developed B- and R-lines and INTSORMIL lines, will facilitate selection in the next phase of the breeding program for acid-soil tolerance.
The program identified the following grain sorghum lines susceptible (poor growth and low yield) to Al^{3+} toxicity. These are: SPRU 94008, IS 30469C-140-2, IS 18758C-603, ICSR 89015, ICSB 95091, SPDM 94024, SPDM 94037, SPDM 94006, SPMD 94014, SPLB 94005, and SPLB 91016. These together with the tolerant lines may be useful in strategic studies.

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Table 1. Grain Yield (t ha⁻¹) of the selected grain sorghum B- and R-lines and forage yield (t ha⁻¹) of the selected forage sorghum and pearl millet lines at Carimagua (1996-II) and Matazul (1997-II), Colombia.

Grain yield, B-lines				Grain yield, R-lines				Forage fresh yield, forage-lines			
Carimagua 1996-II		Matazul 1997-II		Carimagua 1996-II		Matazul 1997-II		Carimagua 1996-II		Matazul 1997-II	
Line	Yield	Line	Yield	Line	Yield	Line	Yield	Line	Yield	Line	Yield
		ICSB 38	2.2			CGM 39/22-1-2	1.8			Pearl millet	
ICSB 73	1.4	* ICSB 73	1.3			CCGM 21/4-3-1	1.9			* ICMV 87001	9.1
ICSB 89	2.3	* ICSB 89	1.0			BF 83-3/48-2-1	1.9			ICMP 92853	11.6
ICSB 90	1.6	* ICSB 90	1.4			CSV-15R	2.0			ICMS 7703	10.0
ICSB 93	2.3					CEM 328/3-3-1-1	2.2			ICMV85404	9.4
ICSB 94	1.6	* ICSB 94	1.0			IS 21658	2.3			ICMV 91773	10.7
ICSB 102	4.0					IS 21629	2.0			ICMV 93751	9.5
ICSB 88004	1.5					*** CEM 336/10-1-1	1.8			* ICMV-IS-85321	
ICSB 88015	1.7	ICSB 88015	1.8	ICSR 74	3.6					IP 18378	13.2
ICSB 89002	2.6	ICSB 89002	2.2			ICSR 102	2.0			* SOSAT-C-28	
		ICSB 89004	2.0			ICSR 110	2.0			* LHGP	
SPSBF 94002	1.4					ICSR 194	2.0	Sorghum		* TGP	
SPMD 94004	2.3	SPMD 94004	2.0	ICSR 89012	6.0			ICSR 93011	7.6	Sorghum	
		SPMD 94006	2.7	ICSR 91008	3.2	ICSR 91008	2.3	ICSR 93024	9.8	ICSR 93024-1	12.1
SPMD 94019	2.7	SPMD 94019	2.1	ICSR 91012	2.1	ICSR 91012	2.0			ICSR 93024-2	17.6
		SPMD 93036	2.1			ICSR 91020-1	2.6	IS 31496	20.6	IS 31496	27.4
SPMD 94045	2.6	SPMD 94045	1.9	ICSR 91020-2	4.1	*** ICSR 91020-2	1.5	IS 13868	12.1	IS 13868	24.8
SPHB 94006	2.3	** SPHB 94006	1.4	ICSR 93033	2.9	ICSR 93033	2.5	GD 47805	8.0		
SPAN 94008	1.4			ICSV 93042	1.8	ICSV 93042	3.0	GD 27668	9.4		
		SPAN 94046	2.3	ICSV 95072	3.2						
SPA2 94013	3.5	SPA2 94013	2.6	ICSV 95091	2.0			Sikuani[1]	12.4	Sikuani[1]	19.8
		* SPA2 94016	1.3			*** ICSV 112	1.2			Sudax Grass[1]	21.0
		SAP2 94021	2.5	IS 30469-1187-2	2.3	IS 30469-1187-2	2.0				
		SAP2 94022	2.4	IS 30469-1187-4	2.0	IS30469-1187-4	2.5				
SPA2 94029	3.0	SAP2 94029	2.2	IS 30469-1187-5	2.3						
SAP2 94039	3.1	SAP2 94039	2.7			ICSR 143	3.1				
						ICSV 95126	1.7				
REAL 60[1]	2.9	REAL 60[1]	2.2	GD 27669	2.9	GD 27669	1.9				
SBL 107[1]	3.3	SBL 107[1]	1.9								
A 2267-2[1]	1.4	A 2267-2[1]	2.4	REAL 60[1]	2.8	REAL 60[1]	2.3				
SPRU 94008[1]	0.8	SPRU 94008[1]	0.3	SBL 107[1]	3.8	SBL107[1]	1.4				
				A 2267-2[1]	1.4	A 2267-2[1]	2.3				
				SPRU 94008[1]	1.3	SPRU 94008[1]	0.2				
Mean	2.2	Mean	1.6	Mean	2.6	Mean	1.6	Mean	10.4	Mean	14.4
SD ±	0.8	SD ±	0.7	SD ±	0.8	SD ±	0.6	SD ±	5.2	SD ±	5.9
CV(%)	29.1	CV(%)	27.4	CV(%)	23.7	CV(%)	29.5	CV(%)	30.3	CV(%)	16.9

* Brought forward as they were found to be promising at other locations

** Line selected but still having A and B matching problems

*** Rejected as they were too tall or found to be susceptible to leaf diseases

1. Controls

Source: ICRISAT/NARS and CIAT (1997a & 1998a)

Table 1. continued

Grain yield, B lines				Grain yield, R lines				Forage fresh yield, forage-lines			
Carimagua 1996-II		Matazul 1997-II		Carimagua 1996-II		Matazul 1997-II		Carimagua 1996-II		Matazul 1997-II	
Line	Yield	Line	Yield	Line	Yield	Line	Yield	Line	Yield	Line	Yield
SPSRP 94002	1.4							ICSR 194	2.0	*TGP[1]	
		SPA2 94021	2.5	IS 30469-1187-2	2.3	IS 30469-1187-2	2.0				
		SPA2 940022	2.4	IS 30469-1187-4	2.0	IS 30469-1187-4	2.5				
SPA2 94029	3.0	SPA2 94029	2.2	IS 30469-1187-5 -	2.3						
SPA2 94039	3.1	SPA2 94039	2.7			ICSR 143	3.1				
						ICSV 95126	1.7				
REAL 60[1]	2.9	REAL 60	2.2	GD 27669	2.9	GD 27669	1.9				
SBL 107[1]	3.3	SBL 107	1.9								
A 2267-2[1]	1.4	A 2267-2[1]	2.4	REAL 60[1]	2.8	REAL 60[1]	2.3				
SPRU 94008[1]	0.8	SPRU 94008[1]	0.3	SBL 107[1]	3.8	SBL 107[1]	1.4				
A 2267-[2]	1.4	A 2267-2[1]	2.3								
SPRU 94008[1]	1.3	SPRU 94008[1]	0.2				.				
Mean	2.2	Mean	1.6	Mean	2.6	Mean	1.6	Mean	10.4	Mean	14.
SE ±	0.8	SE ±	0.7	SE ±	0.8	SE ±	0.6	SE ±	5.2	SE ±	5.9
CV %	29.1	CV %	27.4	CV %	23.7	CV %	29.5	CV %	30.3	CV %	16.9

* Brought forward as they were found to be promising at other locations Source: ICRISAT/NARS and CIAT (1997a).

** Line selected but still has A and B matching problems Source: ICRISAT/NARS and CIAT (1998a).

*** Rejected as they were too tall or found to be susceptible to leaf diseases

1. Controls

Genotype (G) and G x Environment (E) Interactions in Sorghum in Acid Soils of the Oriental *Llanos* of Colombia

Belum V S Reddy[1] and Andres Felipe Rangel[2]

Resumen

La Interacción genotipo (G) por ambiente (E) es importante por la información que brinda para decidir el enfoque de un programa de mejoramiento. La presencia de una interacción G × E sugiere que el programa de mejoramiento debe ser específico para cada ambiente. Análisis realizados en ensayos de sorgo (líneas R y líneas B para producción de grano y líneas forrajeras) conducidos en tres localidades (experimento 1) involucrando una gran variedad de materiales, demostraron una interacción G × E significativa para los tratamientos que influyen en el peso del grano y del forraje. Las líneas fueron caracterizadas en tres niveles de adaptación. Estos fueron: a) líneas ampliamente adaptadas (medias altas y valores de regresión entre 0 y 1), aa) Mejor respuesta a ambientes más favorables (medias altas y coeficientes de regresión significativamente mayores que 1), y aaa) líneas de mejor respuesta a condiciones de acidez del suelo (medias altas y coeficientes de regresión menores de 0).

Estudios específicos sobre niveles de Al^{+3} (experimento 2) involucrando 40, 60 y 80 % de saturación de Al^{+3} pero con un estrecho y seleccionado número de genotipos, mostraron que la interacción G × E no fue significativa para peso de grano y de panoja. Las líneas mostraron una significativa mayor producción de grano a 60% de saturación en comparación a 40% de saturación, contrario a lo esperado. Se puede concluir que la adaptación específica debe ser un objetivo del programa de mejoramiento, considerando que los genotipos estudiados en los diferentes niveles de Al^{+3} fueron seleccionados anteriormente y no representaron una amplia variabilidad. La reducción en la producción de grano no fue tan alta bajo 80% de saturación de Al^{+3} comparado con el incremento en la producción de grano de 40 a 60% de saturación, y que la interacción G× E fue significativa en el experimento 1, el cual involucró una mayor variedad de genotipos. Las diferencias observadas en el comportamiento de los genotipos bajo niveles de saturación de Al^{+3} pueden ser debidas a diferencias en los posibles mecanismos de tolerancia que operan en estas líneas tolerantes.

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Introduction

Vast areas of plains in Bolivia, Brazil, Colombia, and Venezuela in Latin America with agro-pastoral systems, traditionally used for livestock production can be incorporated into more productive sustainable systems by diversifying the agro-pastoral systems with various cropping systems. There is growing awareness among the scientists in the national systems in the region about the potential of sorghum and pearl millet as crops that raise the productivity of the systems (ICRISAT, NARS and CIAT, 1995).

Sorghum genotypes differ in their response to different growing conditions. Several studies elucidated the implications of G x E interactions in breeding programs in sorghum and other crops under near neutral fertility conditions. Significant G x E interactions indicated the need to direct the breeding for specific adaptation. Absence of interactions emphasized the value of selecting the materials for wide adaptability (Allard, 1960).

Gourley (1983) reported that G x E interactions are possible under different acid-soil conditions and evaluation techniques and, therefore, suggested that the sorghum breeding effort should be specifically directed for low input, acid-soil conditions. Further, Gourley (1991) observed large differential variability in the amounts of various elements accumulated in the leaves of various genotypes when grown under different acid-soil locations. Flores et al. (1988) studied G x E interactions in sorghum under various acid-soil conditions. However, G x E interaction studies in sorghum grown under acid-soil conditions are limited. The purpose of this paper is to summarize G x E interactions information in sorghum based on the data collected during the course of screening sorghum lines for acid-soil tolerance in the Oriental *Llanos* of Colombia.

Materials and methods

The grain sorghum R-lines (83) and B-lines (87) and forage sorghum lines (33) selected in tests at CIAT, Palmira, (Valle del Cauca) (December 1995-May 96) and Quilichao (Cauca) and La Libertad, Villavicencio, Meta (May-Aug 1996) tests were evaluated at Quilichao (55% Al^{3+} saturation), La Libertad *(66%* Al^{3+} saturation) and Carimagua (71% Al^{3+} saturation) during September 1996-January 1997 season. The experiment is designated as *experiment 1.*

Data were analyzed for G x E interactions through ANOVA using the locations as main factors and genotypes as sub-factors and for stability parameters based on Eberhart and Russell (1966). The data on soil characteristics at these locations are reported by Reddy et al. (1998).

Further, a selected set of R lines (12 in all) were studied for their response under three different Al^{3+} (80,60, and 40%) saturation using the Al^{3+} levels as the main plots and the genotypes as the sub-plots at Matazul farm (Meta) with three replications during July-December 1997 season. Data were analyzed following the split-plot design. Fifteen days before the trial was planted, 625 kg ha^{1}, 1536 kg ha^{-1}, and 3339 kg ha^{1} lime (dolomite calcareous) were applied to raise Al^{3+} saturation to 80, 60, and 40% levels.The land preparation and other cultural operations were similar to other trials in the locations. The experiment is designated as *experiment 2.*

It is possible that resistance mechanisms might differ depending upon the Al^{3+} levels (or environments), and thus genotypes with varied selection histories might vary in their resistance mechanisms. It is likely that ICRISAT-bred lines and the INTSORMIL-selected lines (e.g. Real 60) have different mechanisms. Malate and phosphate exudates contribute to Al^{3+} tolerance, as in a wheat variety which is controlled by dominant alleles at least at two loci (Pellet et al., 1996). We need to study the resistance mechanisms and their genetics in the selected sorghum lines.

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Table 1. ANOVA for various traits of sorghum R-lines and B-lines, forage sorghum and pearl millet lines, different locations, 1996, season II.

Source	Days to flowering			Plant height (cm)			Agronomic score			Forage weight[1] ($t\ ha^{-1}$)		
	Df	MSS		Df	MSS		Df	MSS		Df	MSS	
R lines (Sorghum)												
Replications in stations (R)	6	318.9	**	6	0.463	**	6	4.34	**	—	—	
Stations (S)	2	509.82		2	0.457		2	3.89		—	—	
Genotype (G)	69	143.1	**	69	0.328	**	69	3.94	**	—	—	
S x G	137	39.6	**	135	0.054		138	0.94	**	—	—	
SE ±	319	20.4		304	0.044		414	0.68		—	—	
B lines (Sorghum)												
Replications in stations (R)	6	200.4	**	6	0.224	**	6	1.05		—	—	
Stations (S)	2	1387.2	**	2	0.09		2	89.2	**	—	—	
Genotypes (G)	92	124.3	**	92	0.226	**	92	2.91	**	—	—	
S x G	168	28.6	**	165	0.004		184	1.21	**	—	—	
SE ±	364	18.9		364	0.038		552	0.78		—	—	
Forage lines (Sorghum and Pearl Millet) Replications in stations (R)	6	26.7		61	0.076		6	3.66	**	6	17	*
Stations (S)	2	361.9	**	2	0.289	**	2	0.45		2	283.9	**
Genotypes (G)	13	158.4	**	13	0.301	**	13	6.53	**	13	81.3	**
S x G	21	64.6	**	22	0.144	*	26	1.84	*	20	30.6	**
SE ±	50	30.1		56	0.086		78	0.49		54	8.9	

*= significant at $P < 0.05$; and ** = significant at $P < 0.01$

Source: ICRISAT, NARS and CIAT, 1997.

Table 2. Effect of Al^{+3} saturation levels on performance of sorghum lines, Matazul, Colombia, July - Dec 1997.

Al^{+3} Saturation	Early vigor[1]	Days to flowering	Green leaf area[2]	Agronomic score[3]	Head weight[4]	Grain weight[4]
40	1.52^{b5}	76.63^{a}	1.55^{b}	1.88^{b}	2.32^{b}	1.71^{b}
60	1.41^{b}	75.77^{a}	1.66^{b}	2.05^{b}	2.61^{a}	1.94^{a}
80	2.13^{a}	73.97^{b}	2.16^{a}	3.25^{a}	1.92^{c}	1.43^{c}
SE±	0.20	0.83	0.07	0.08	0.20	0.15

1. Scale 1 to 5, where 1= most vigorous, and 5 = least vigorous
2. Scale 1 to 5, where 1= maximum green leaf area, and 5 = least green leaf area
3. Scale 1 to 5, where 1 = most desirable, and 5 = least desirable
4. t ha^{-1}
5. values followed by the same letter within a column do not differ significantly (*P*< 0.05)

Table 3. Performance of sorghum lines across all Al^{3+} saturation levels, Matazul, Colombia, July to December 1997.

Pedigree	Early vigor[1]	Days to flowering	Green leaf area[2]	Agronomic score[3]	Head weight[4]	Grain weight[4]
REAL 60	1.1	72.6	2.0	1.8	2.7	2.0
ICARAVAN	1.6	73.6	2.2	1.8	2.5	2.0
SBL 107	1.3	71.3	2.2	2.3	2.3	1.7
A 2267-2	1.6	87.9	1.7	2.7	2.7	1.7
SPRU 94008	2.7	71.3	1.9	4.4	0.8	0.4
CEM 342/1-2-2	1.7	75.6	1.7	2.6	1.4	1.2
ICSV 902	2.2	72.2	1.8	2.1	1.8	1.4
ICSR 102	1.2	74.1	1.8	2.4	2.6	2.0
ICSR110	1.2	73.4	1.2	2.4	2.9	2.2
ICSR 194	1.8	75.6	1.6	1.6	2.8	2.1
IS 30469-1187-2	2.2	77.6	1.7	1.6	2.4	1.8
ICSR-143	1.8	80.4	1.9	3.1	2.5	1.9
Mean	1.7	75.6	1.8	2.4	2.3	1.7
SE±	0.45	4.53	0.27	0.77	0.61	0.48

1. Scale 1 to 5, where 1 = most vigorous and 5 = least vigorous
2. Scale 1 to 5, where 1 = maximum green leaf area and 5 = least green leaf area
3. Scale 1 to 5, where 1 = most desirable and 5 = least desirable
4. t ha^{-1}

Pearl Millet in Brazil - New Approaches and Prospects

Fredolino G. dos Santos, Jose A. Santos Rodrigues, Robert E. Schaffert, Carlos A. Vasconcellos, Gilson V. E. Pitta, Israel A. P. Filho, and Dea A. Martins Netto[1]

Resumen

El millo perla se ha convertido en un cultivo alternativo en Brasil debido al mejor nível tecnológico en las áreas sin sistemas de arado. Esta especie es cultivada en Brasil porque enriquece el contenido orgánico de los suelos y el uso de su grano como alimento por la industria avícola, donde este cultivo proporciona 60 a 100% de la energía. Las principales áreas de producción son en el sistema "safrinha" del Cerrado (en la región Centro-Oeste), con siembras en los meses de Febrero o Marzo, e immediatemente después de la cosecha de la soya. La baja fertilidad del suelo, la sequía, las enfermades, y las altas temperaturas fueron consideradas como los mayores problemas que afectan a este cultivo en esta región. Varias líneas A y B asi como poblaciones de millo perla son conservadas en el Centro Nacional de Pesquisa para Milho e Sorgho en Siete Lagoas. Los avances en fitomejoramiento se mencionan en este artículo, que indica que la variedad de polinizacion liberada BRS 150 fue libreda para su cultivo en sistemas sin arado en Brasil.

Pearl millet (*Pennisetum glaucum (L.)* R.Br.) can be considered to be the sixth most important crop in economic terms, in the tropical area of the world, principally in the semi-arid regions. In Brazil, recently, due to an increase in the level of technology by the farms and in the areas under "no tillage systems", either for grain or for feeding beef cattle, pearl millet has become a very important alternative crop in the *Cerrado* areas of the Central part of Brazil.

The pearl millet plant, due to such characteristics as high-yield potential, high growth rate and high tillering ability, has adapted well to harsh environments. In Brazil, it is usually sown in summer in the Central and Southern areas, where up to 10-15 tons of dry matter ha^{-1} are obtained. In winter in the Northeast region, on the other hand, under semi-arid conditions, these yields normally drop to less than 50%.

The grain production of pearl millet can be used almost entirely in poultry industries. On average, 60 -100% of the energy component of the final products can be met by pearl millet as a viable alternative.

The demand for grain in Brazil has increased significantly in this last decade. The dependence on grain stocks, principally of maize, and the close relationship of maize productivity with precipitation make the demand for grain even greater. In this context, pearl millet appears to be a viable crop of economic significance to fulfil this grain supply gap.

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In Brazil, the crop-growing areas currently are Minas Gerais, Goias, Bahia, Mato Grosso, Mato Grosso do Sul, Sao Paulo, Parana, and Rio Grande do Sul States. It is estimated that over 2 million ha are planted with pearl millet under "no till systems", principally, in the Cerrado area of the Center-West region. In this area, a particular planting system called *safrinha* has increased and is spreading very fast. This starts usually towards end of summer planting season, usually in mid-February or March just after the soybean harvest.

The *safrinha* is considered to be a low-cost production system and may contribute greatly to the maintenance of the overall sustainability of the cropping system of the Cerrados.

Through the breeding techniques of population improvement, new cultivars are being developed to cope with some limiting environmental plant-growth conditions such as low soil fertility, drought, disease, and high temperature.

The majority of the cultivars presently in use were introduced from non-tropical areas so the adaptation for tropical conditions is of great importance. The EMBRAPA Milho e Sorgo Germplasm Bank, in Sete Lagoas, comprises 1019 varieties, 56 male-sterile lines, 518 R-lines, where 15 are resistant to downy mildew and 6 have photoperiod sensitivity genes.

In 1998, the variety BRS 1501 was released by EMBRAPA Milho e Sorgo, for no-till systems with average grain yield of close to 2.5 t h^{-1}. The results of some plant parameters of some of the selected materials are shown in Tables 1 and 2.

Table 1. Average values of plant height (cm), green and dry matter yield (t ha^{-1}).

Cultivars	Height (cm)	Yield (t ha^{-1}) Forage mass	Dry mass
CMS 03	169^{abc}	45.78^{a}	7.73^{a}
CMS 1	181^{a}	44.67^{a}	7.15^{ab}
BN 2	175^{ab}	47.73^{a}	7.08^{ab}
9317461	174^{abc}	36.14^{b}	6.43*
9317484	161^{cd}	37.59^{b}	6.31^{bc}
9317464	163^{bcd}	37.29^{b}	6.20^{bcd}
CMS 2	145^{e}	35.86^{b}	5.79^{cd}
9317006	169^{abc}	31.55*	5.38^{cd}
NPM1-ALT	152^{de}	29.14^{cd}	5.13^{c}
9317482	166*	31.68^{bc}	5.12^{c}
NPM1-BX	128^{f}	23.76^{de}	3.86^{e}
NPM3-ALT	114^{g}	20.98^{e}	3.39^{e}
Mean	158	35.18	5.80
C.V (%)	7.90	16.57	18.08

Items followed by the same letters do not differ significantly at 0.05 probability.

Table 2. Minimum and maximum values of plant height(cm) and biomass yield (t ha^{-1}) in three different environments, Brazil, 1998.

	Height (cm)		Yield (t ha-^{1})			
			Forage mass		Dry mass	
Cultivars	Min.	*Mix.*	Min.	Max.	Min.	Max.
CMS 03	150	206	39.75	55.60	6.09	9.25
CMS 1	160	202	38.67	55.60	6.34	8.46
BN 2	147	223	40.50	55.20	6.55	7.55
9317461	150	211	30.08	42.93	6.39	7.70
9317484	142	195	33.00	46.27	4.49	7.63
9317464	150	188	31.83	44.13	5.40	7.06
CMS 2	107	189	31.58	40.00	5.35	6.12
9317006	152	199	29.58	33.07	4.47	6.05
NPM1-ALT	130	208	21.00	36.93	3.25	6.15
9317482	132	218	25.92	37.87	4.41	6.43
NPM1-BX	85	192	15.92	28.93	2.76	4.44
NPM3-ALT	77	184	13.33	28.53	2.23	4.36

Session IV: Proposals and Future Plans

Network Trials : Prospects and Problems

Andres Felipe Rangel[1] and Belum V S Reddy[2]

Resumen

Los ensayos de la red de investigacion son el medio de transferencia de los productos del proyecto a los países miembros. Ellos facilitan la evaluación y selección de materiales dentro de los sistemas de producción específicos en cada región. Igualmente, se espera que los países miembros puedan evaluar sus propios materiales dentro de los ensayos de la red y crear la posibilidad de intercambio de semillas entre ellos.

Entre 1997 y 1998, el proyecto suplió un total de 21 grupos de ensayos, cada uno conteniendo tres ensayos para grano (sorgo mantenedores de esterilidad y restauradores de fertilidad) y para forraje (sorgo y millo perla). Sin embargo, sólo los datos de dos ensayos de sorgo para grano provenientes de Honduras y tres de sorgo y millo perla para forraje provenientes de Colombia, fueron recibidos, lo cual indica una pobre respuesta. Los datos fueron analizados y los materiales para grano y forraje más promisorios de sorgo y millo perla fueron identificados para las diferentes regiones y semestres. La necesidad de aceptación de la Carta de Transferencia de Material (MTA, sigla en Inglés) cuando se recibe el material para mantener los productos de la investigación en el dominio público, son indicados.

Introduction

Transfer of the acid-soil tolerant sorghum and pearl millet A/B lines and open-pollinated varieties developed is one of the most important aspects of the project, A Research and Network Strategy for Sustainable Sorghum Production for Latin America (ICRISAT, NARS, and CIAT, 1995). Networking of the locations and the scientists in the region (Bolivia, Brazil, Colombia, Honduras, and Venezuela) is one of the means of achieving this objective. More specifically, the network trials are expected to achieve the following:

- Making grain sorghum A/B lines and R lines and forage sorghum and pearl millet lines available to the National Agricultural Research Systems (NARS) in the region.
- Evaluating the selected products over a wider region to enable us in further selection of the materials for specific production systems.
- Providing opportunities to evaluate the NARS materials in the network trials in various locations and facilitate exchange of seed materials among the members.
- Facilitating exchange of ideas and knowledge among the members of the network.

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Introduction and testing of grain sorghum A/B and R-lines in the Oriental Llanos of Colombia enabled us to identify a set of promising A/B-lines and R lines of grain sorghum and varieties/open-pollinated populations of forage sorghum and pearl millet. Further, preliminary hybrids made between ICRISAT A/B-lines and the ICRISAT and INTSORMIL (International Sorghum and Millet) program's R-lines, selected for acid-soil tolerance, were tested and the selected hybrids, A/B-lines, and varieties/R-lines were seed-increased. The details and the results of these tests are reported by Reddy et al. (1998) and Reddy and Rangel (1998) elsewhere in there proceedings. The selected products were arranged as network trials and supplied to the member countries in the region.

The purpose of this presentation is to provide details of the trails and to summarize the data received from members. Also, the difficulties encountered in running the trials are discussed in an attempt to find solutions.

Materials and Methods

Grain sorghum A/B lines (378 pairs) and R lines (784), and forage sorghum lines (94), and pearl millet materials (68) were introduced from ICRISAT, Patancheru, India into Colombia through CIAT, Cali during the first semester of 1996 (Dec 95 to May 96). Successive evaluations of these materials in acid-soil conditions at different locations in Colombia including hillsides (Quilichao, Cauca) and lowlands (La Libertad, and Matazul, Meta) enabled us to identify acid-soil tolerant and leaf-disease resistant lines. These lines were arranged as three trials (grain sorghum B-lines trial with 32 entries, grain sorghum R-lines trial with 49 entries, and forage trial with 6 sorghum lines and 8 pearl millet lines) in the second semester of 1997 and these were dispatched to private and public sector scientists in the region, as follows:

1. *Private sector.* One set to Dr. Gino Malagutti (Venezuela)[1]
2. *Public sector:* Two sets to Dr. Robert Schaffert (EMBRAPA, Brazil); one set each to Dr. Jose Nildo Tabosa (IPA, Brazil), Dr. Pedro Jose Garcia (FONAIAR Venezuela), and Dr. Francisco Gomez (ZAMORANO, Honduras); and three sets to Dr. Jaime Bemal (CORPOICA, Colombia).

Selected lines from these trials formed the test materials for new set (20 B lines, 20 R line, 4 forage sorghum lines and 11 pearl millet lines) of trials (ICRISAT, NARS and CIAT, 1998), and these were dispatched again to the collaborators during the second semester of 1998, as follows:

1. *Public sector:* One set each to Dr. David Tejada Inga (la Paz, Bolivia), Dr. Jose Nildo Tabosa (IPA, Brazil), Dr. Maricio Antonio Lopez (EMBRAPA, Brazil) Mr Juan Manuel Caicedo (UNILLANOS, Colombia), Dr. German Obar (CIAT, Colombia), Dr. Edmundo Barrios (CIAT, Colombia), Dr.Rafael Arturo Mateo (ZAMORANO, Honduras), and Dr. Pedro Jose Garcia (FONAIAP Venezuela); and four sets to Dr. Jaime Bemal (CORPOICA, Colombia)

Thus a total of nine sets of trials in 1997 and 12 sets of trials in 1998 were supplied so far.

1 .Trial already conducted by Dr. Richelil (Hibridos Mejorados Venezolanos, HIMECA)

Results and Discussion

Results were received for grain sorghum B- and R-line network trials from ZAMORANO, Honduras (1997, season II), and for forage sorghum and pearl millet network trials from La Libertad, Colombia (1997, Season II). Data for grain and forage pearl millet trials of 1997, season II and 1998, season I from La Libertad were also received.

a. Honduras Network Trials, 1997

The soils at the north part of Honduras are acidic (A13+: 36-55%, pH: 3.9 to 4.7) and have high organic content (6.65 to 8.80) like the Quilichao soils in Colombia.

The grain sorghum B-line trial consisted of 32 test entries. The trial mean for grain yield was 2.6 t ha^{1}. The acid-soil tolerant line, Real 60 yielded 3.0 t ha^{1} (SD ± 1.18). The coefficient of variation of the trial was very high (46%). The B lines which yielded 2.9 t ha^{-1} and above were selected. The best two entries in the trial were ICSB 93 (on A_1 cytoplasm) and SPA_2 94029 (on A_2 cytoplasm). All the selected B lines except ICSB 93 (selected at Carimagua, 1996 season II) were selected at Matazul in 1997 season II (Reddy et al., 1998). Other details can be found in Table 1.

The grain sorghum R-line trial consisted of 40 test entries. The trial mean for grain yield was 2.5 t ha^{-1} (SD ± 1.09). The coefficient of variation was very high (44%). The acid-soil tolerant control line, Real 60 produced grain yield of 1.7t ha^{-1}. The best three R-lines that produced the highest grain yield (4.2 to 3.6 t ha^{-1}) were ICSR 110, ICSV95072, and CEM 336/10-1-1. The details are shown inTable 1. All R lines, except CEM 339/1-1-1, IS 18758C-710-3, CCGM 9/8-1-3, ICSV 95072, and BF 86-5/20-2-1 were selected at Matazul during 1997 season II (Reddy et al., 1998).

Thus, the majority of the B lines and R lines that were found to be promising at Tegucigalpa, Honduras belonged to the sets of the lines selected at Matazul, 1997 season II. Therefore, it appears that environment and genotype response in Tegucigalpa (Honduras) correspond to those in Matazul (Colombia).

b. Colombia forage network trial, 1998

The forage sorghum and pearl millet network trial of 1998 was conducted at La Libertad during 1998 season I. The soils at La Libertad are acidic (pH: 4.84, *66%* of AP^{3+} saturation). The trial consisted of 6 forage sorghum lines and 8 forage pearl millet open-pollinated varieties. Three sorghum and three pearl millet lines were selected based on their high fresh-fodder yields. The control fodder sorghum variety Sudax produced 8.4 t ha^{-1} of fresh-fodder (SD ± 2.1). The best sorghum entries with highest fresh-fodder weight were IS 13868, IS 31868, and ICSR 93024-2. The variety ICSR 93024-2 has a brown midrib, indicating that the fodder is highly palatable. Forage pearl millet varieties, ICMV 7703, ICMP 92853, and ICMV 93751 have produced 7.5 to 8.31 ha^{-1} of fresh-fodder. Considering that they take less than 55 days to flower, these may very suitable for drought-prone environments and seasons. Further details about the selected genotypes may be found in Table 2.

c. Colombia grain/forage pearl millet (extended entries) trial

The grain/forage pearl millet trials with 38 test entries were conducted at La Libertad during 1997 season II (Oct 1997 to Jan 1998) and 1998 season I (March to June 1998). The soils at the trial site are similar to those mentioned above. .

Season II of 1997 was dry with only 210 mm rainfall during the trial period. Most of the rainfall (83%) was received in the first 30 days after sowing. Data of fresh-fodder weight were not available; rather grain weight data were received. Hence, the genotypes in this trial were selected based on grain weight.

The characteristics of the selected genotypes are given in Table 3. The trial grain weight mean was 1.2 t ha^{-1} (SD ± 0.33). The two highest grain-yielding genotypes were ICMR 312 and ICMP 89410 in 1997 season II trial.

Season I of 1998 was wet, with 952 mm rainfall received during the crop growth; the rainfall was evenly distributed. Data on fresh forage weights were taken and, hence, the genotypes were selected based on fresh-folder weights. The characteristics of the selected genotypes are given in Table 3. The trial fresh forage weight mean was 23.8 t ha^{-1} in 1998 season I (SD ± 4.5). The two highest-yielding (fresh forage) genotypes were ICMP 92853 and ICMV 87001 in 1998 season I trial.

The Consultative Group on International Agricultural Research (CGIAR) hopes to keep the products of the project in the public domain. Therefore, it is expected that the scientists should receive the seed materials upon signing of the Material Transfer Agreement (MTA) Appendix 1.

Overall, the data return by the members is not encouraging; members may come up with ways of improving their participation in the network trials. Also, members can come forward to make use of the trials to test their own genotypes in other locations/countries through the trials.

Acknowledgement

The authors wish to thank the various cooperating member scientists, in particular Drs. Jaime Bemal (CORPOICA, Colombia) and Rafael Arturo Mateo (ZAMORANO, Honduras) who conducted the trials and generously supplied the data. The authors also acknowledge the grant received from the Inter-American Development Bank (IDB) in support of this work.

Table 1. Characteristics of selected grain sorghum B-lines and R-lines evaluated at Tegucigalpa, Honduras, 1997, season II.

Sorghum genotypes	Early vigor[1]	Days to flowering	Agronomic score[2]	Disease score[3]	Grain Yield(t ha^{-1})	Included in Matazul 1998-II
B-lines						
ICSB 38	1.0	68	1.0	1.0	3.2	yes
ICSB 73	2.0	70	3.0	1.0	2.9	yes
ICSB 93	3.0	65	3.0	2.0	3.3	no
SPMD 94004	4.0	64	3.0	1.0	3.1	yes
SPMD 94006	3.0	64	3.0	1.0	2.9	yes
PSMD 94045	4.0	67	3.0	1.0	3.1	yes
SPA2 94013	2.0	64	3.0	1.0	3.0	yes
SPA2 94029	3.0	66	3.0	2.0	3.3	yes
Controls						
Real 60	3.0	64	3.0	1.0	3.0	yes
SPRU 94008	4.0	64	3.0	1.0	1.7	yes
Mean	2.86	65.00	2.97	2.03	2.60	
SD ±	0.00	6.54	0.00	0.87	1.18	
CV %	0.00	10.07	0.00	42.81	45.95	
R-lines						
CEM 336/10-1-1	2.0	70	2.0	1.0	3.6	no
BF 83-3/48-2-1	2.0	73	2.0	1.0	2.9	yes
CEM326/11-5-1-1	1.0	66	2.0	1.0	2.9	no
ICSR 91020-1	2.0	74	2.0	1.0	2.8	yes
CEM 339/1-1-1	2.0	65	2.0	1.0	3.3	no
IS 18758C-710-3	2.0	72	2.0	1.0	3.4	no
CCGM 9/8-1-3	3.0	69	3.0	1.0	3.1	no
ICSR 91008	4.0	63	3.0	1.0	2.9	yes

Continued

Table 1. continued

Sorghum genotypes	Early vigor[1]	Days to flowering	Agronomic score[2]	Disease score[3]	Grain Yield(t ha^{-1})	Included in Matazul 1998-II
ICSR 91012	3.0	69	3.0	1.0	3.2	yes
ICSV 95072	4.0	71	3.0	1.0	3.7	no
CGM 39/22-1-3	4.0	65	4.0	1.0	3.3	no
ICSR 110	3.0	66	4.0	1.0	4.2	yes
BF 86-5/20-2-1	3.0	72	4.0	1.0	3.0	no
Controls						
Real 60	2.0	67	2.0	1.0	1.7	yes
SPRU 94008	3.0	69	3.0	2.0	2.3	yes
Mean	3.5	70.0	3.3	2.0	2.5	
SD ±	0.0	6.2	0.1	0.8	1.1	
CV %	0.0	8.7	2.4	38.2	44.3	

1. Scale 1 to 5, where 1 = most vigorous and 5 = least vigorous
2. Scale 1 to 5, where 1 = most desirable and 5 = least desirable
3. Scale 1 to 9, where 1 = free of leaf diseases, 2 = 1-5% of leaf area affected, 3 = 6-10%, 4 = 11-20%, 5 = 21-30%, 6=31-40%,8=51-75% and 9=>75% of leaf area affected.

Source: Network trials, Honduras 1997, season II.

Table 2. Characteristics of selected forage sorghum and pearl millet varieties evaluated at La Libertad, Colombia, 1998, seasonI.

Genotypes	Early vigor[1]	Days to flowering	green leaf area[2]	Agronomic score[3]	Lodge[4]	Leaf diseases[5]	Forage weight(t ha^{-1})
Sorghum							
IS 13868	2.0	66	2.3	1.7	2.0	2.0	13.5
ICSR 93024-2	5.0	65	2.7	2.0	1.7	2.3	8.1
IS 31868	3.7	67	2.3	2.0	1.7	2.3	10.9
Pearl millet							
ICMV 93751	2.3	48	2.0	2.0	2.0	2.3	7.5
ICMP 92853	2.7	54	2.0	2.0	2.7	2.3	7.8
ICMS 7703	2.0	50	3.0	2.5	2.5	2.5	8.3
Control							
Sudax Grass (Sorghum)	4.0	67	2.3	2.0	1.0	2.0	8.4
Mean	3.2	58	2.5	2.0	1.9	2.5	7.5
SD ±	0.5	2.2	0.8	0.6	0.6	0.6	2.1
CV %	16.4	3.7	34.0	28.4	31.3	23.1	28.2

1. Scale 1 to 5, where 1 = most vigorous and 5 = least vigorous
2. Scale 1 to 5, where 1 = maximum green leaf area and 5 = least green leaf area
3. Scale 1 to 5, where 1 = most desirable and 5 = least desirable
4. Scale 1 to 5, where 1 = 0-10 % plant lodged, 2 = 11-25%, 3 = 26-50%, 4 = 51-75% and
5. Scale 1 to 9, where 1 = free of leaf diseases, 2 = 1-5% of leaf are affected, 3 = 6-10%, 4= 11-20%, 5 = 21-30%, 6 = 31-40%, 7 = 41-50%, 8 = 51-75% and 9 = > 75% of leaf area affected.

Source: Network trials, La Libertad, Colombia. 1998 season I.

Table 3. Characteristics of the selected forage pearl millet varieties evaluated at La Libertad, Colombia, 1997 season II and 1998 season I.

Genotypes	Early vigor[1]	Days to Flowering	Green leaf area[2]	Agronomic score[3]	Lodge[4]	Weight[5]
1997-II						
ICMP 89410	1.3	36	6.7	2.3	2.3	1.8
IPC 1309	1.7	38	7.3	3.0	2.3	1.6
ICMR 501	2.0	33	7.0	3.0	1.7	1.5
ICMP 155	2.3	36	7.7	3.3	3.0	1.6
ICMR 312	2.0	34	7.5	3.5	2.5	1.8
IP 18378	1.0	40	6.7	1.7	3.0	1.3
Mean	2.0	38	7.0	3.0	2.6	1.2
SD ±	0.6	3.8	0.6	0.6	0.7	0.33
CV %	28.9	8.8	8.6	20.6	26.8	28.0
1998-I						
ICMP 87200	2.3	46	2.0	1.0	2.0	29.8
LGHP	2.3	45	2.3	1.3	2.3	28.0
IP 18378	3.0	47	2.7	1.7	2.3	28.8
CMP 87001	2.3	45	2.3	1.7	1.3	30.9
ICMP 92853	2.3	44	2.3	1.7	2.0	30.8
NCD2	2.3	47	2.0	2.0	1.7	28.3
ICMV IS 89305	2.3	45	2.3	2.0	2.3	29.2
ICMV IS 91203	2.7	45	2.3	2.0	1.7	28.9
Mean	2.6	44	2.6	2.5	1.9	23.8
SD ±	0.77	2.4	0.47	0.64	0.39	4.5
CV %	30.2	5.4	17.9	25.8	19.8	19.1

1. Scale 1 to 5, where 1 = most vigorous and 5 = least vigorous
2. Scale 1 to 5, where 1 = most desirable and 5 = least desirable
3. Scale 1 to 5, where 1 = maximum green leaf area and 5 = least green leaf area
4. Scale 1 to 5, where 1 = 0-10 % plant lodged, 2 = 11-25%, 3 = 26-50%, 4 = 51-75% and 5 = 75 -100%
5. t ha^{-1} grain in 1997 season II.

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Standard Order Form (Material Transfer Agreement) for Genetic Material Developed at ICRISAT

I/We order the following genetic material in the form of seed/vegetative propagules/ tissue samples/DNA:

S.No	Pedigree	Source	Quantity	Remarks

This genetic material has been developed by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) with public funds provided through the Consultative Group on International Agricultural Research (CGIAR) by donors from around the world. Hence, I/we agree the material contained herein is furnished by ICRISAT under the following conditions:

1. ICRISAT is making the material indicated above or in the attached list available as part of its policy of maximizing the utilization of genetic material for research. The material developed by ICRISAT is made freely available for any agricultural research or breeding purposes.
2. Recipients are free to commercialise ICRISAT research products in the form they are provided with due notification to ICRISAT. Prior to the application of any form of intellectual property rights (IPR) on this germplasm and related information, written permission must be obtained from ICRISAT. Moreover, while ICRISAT recognizes the validity of IPR, it reserves the right to distribute all material in accordance with paragraph (1) above.
3. The recipient agrees that any subsequent person or institution to whom they provide samples of this material is bound by these same provisions.
4. Although the materials and associated information being supplied by ICRISAT were developed following careful and comprehensive research, ICRISAT makes no warranties as to the safety or title of the material nor as to the accuracy of correctness of any passport or other data provided with the material. Neither does it make any warranties as to the quality, viability, or purity (genetic or mechanical) of the material being furnished. The phytosanitary condition of the material is warranted only as described in the attached phytosanitary certificate. The recipient assumes full responsibility for complying with the recipient nation's quarantine or biosafety regulations and rules as to import or release of genetic material.
5. The recipients agree to furnish ICRISAT performance data collected during evaluations. Recipients should give due acknowledgement to ICRISAT in their reports for having provided the source material used for their research or to derive a process or product.

Place and date: **Indentor's signature**

Name and institutional affiliation of the person requesting the genetic material:

Address:

Shipping address (if different from the above):

Pearl Millet as a Component of Sustainable Production Systems in Latin America: A Research and Network Strategy

C. T. Hash [1]

Resumen

Millo perla (Pennisetum glaucum (L.)R. Br.) *es una especie gramínea, robusta, annual, y diploide (2n=2x=14 cromosomas). Este artículo informa acerca del origen, la domesticación, y describe como la tolerancia del millo perla a suelos salinos con una baja fertilidad y a suelos ácidos, le permite al milo terner una ventaja en la producción de biomasa en estos ambientes con respecto a otros cultivos. Los usos económicos del millo perla son varios: su grano como alimento, sus tallos verdes o secos como forraje, y sus residuos para enriquence el contenido orgánico del suelo. Estas cualidades están permitiendo su rápida extensión en los suelos ácidos de las sabanas de América Látina y en otros lugares similares en el mundo. Debido a estas carecterísticas,se ha desarrollado este proyecto, cuyos objectivos buscan obtener alta biomasa y baja sensibilidad al fotoperíodo, tolerancia a los suelos ácidos, y resistencia a enfermedades foliares, especialmente roya. Los participantes en estas investigaciones se indican en este artículo.*

As described in my earlier presentation on the current IDB-supported project, the Inter American Development Bank (IDB) provided US$250000 for the period 1996-1997 to support a limited program of sorghum and pearl millet improvement research in tropical Latin America. This project falls under the umbrella of the Systemwide Ecoregional Program for Enhancing Agricultural Research in Tropical America, which is coordinated by CIAT. Partners in this project include ICRISAT, CIAT, and most importantly, the national programs of Brazil, Colombia, Honduras, and Venezuela. This initial phase was extremely productive and cost effective, stimulating IDB to support a second phase for 1998-1999. The purpose of this presentation is two-fold. First, to provide all of you with a bit more information on pearl millet—which is by far the less well-known of the two commodities under investigation in this project. And second, to present for your consideration a proposal to expand the scope of regional research collaboration on this crop that is so well adapted to soil conditions typical of the acid-soil savannas of Latin America.

Pearl Millet

Pearl millet *(Pennisetum glaucum* (L.) R. Br.; with many synonyms) is a robust, annual, diploid (2n = 2x = 14 chromosomes) grass with a high tillering capacity. It is a highly cross-pollinated species and is grown for grain (food and feed), forage, fuel, construction material, and biomass. Pearl millet was domesticated about 5000 years ago in Africa. It spread to eastern and southern Africa and to the Indian subcontinent

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about 3000 years ago. There are currently about 28 million ha sown to this crop each year, mostly in Africa and the Indian subcontinent. However, there are about 2.5 million ha of this crop sown in the Americas (mostly in the tropics), and it is here where I see the greatest potential for expanding the area sown to the crop.

Pearl millet today is still primarily a subsistence crop of low-resource farmers in the hot semi-arid tropics. The crop is primarily grown under rainfed conditions. Compared to other tropically adapted cereals, pearl millet is tolerant to drought stress, high temperatures, and sandy soils with low water-retention capacity. It is also tolerant to soils of low inherent fertility having high levels of Al^{3+} saturation and low levels of available N and P.

In tropical America, pearl millet has only recently begun to demonstrate its potential. For example, in Brazil in 1985 less than 50 000 ha were sown to this crop, mostly as forage or as a dual-purpose grain and forage crop in the semi-arid northeast. Elsewhere in the region pearl millet was known, if at all, as a minor forage crop. However, there have recently been some big changes brought on by the move to no-till agricultural production systems in the Cerrados region of Brazil. In 1998, pearl millet was sown on an estimated 2 million ha in Brazil, primarily as a mulch component of no-till soya production systems. Pearl millet contributes to these systems by smothering weeds, protecting the soil surface from the impact of raindrops and enhancing moisture infiltration, thus reducing soil erosion. It also serves as a biological plow, retrieving leached nutrients from some depths and bringing them closer to the surface where they are available to other crops. Finally, the organic matter from pearl millet takes the place of active clays as the site of cation exchange capacity, facilitating retention of fertilizers in the surface horizon of the soil where roots of other crops in the system can most readily gain access to them. Because of the reduced production costs and increased yields possible when using pearl millet as a mulch component in no-till soya production systems, especially in the acid-soil savannas, the pearl millet area in Brazil is now expanding rapidly.

I expect that agriculturalists in acid-soil savannas elsewhere in Latin America, and in fact worldwide, will soon discover the utility of pearl millet in such systems. Hence I propose that we join together to identify a range of pearl millet varieties that can better meet their needs for improved cultivars for grain, forage, and biomass production. A modest proposal to increase regional research activities in this area is outlined below. The purpose of this proposal is to serve as a starting point for discussion. It is very preliminary in nature and I would welcome any and all constructive suggestions that you may have that would improve its cost-effectiveness, the probability of being funded, or would otherwise contribute to a successful, high-impact outcome.

Objectives

The current IDB project has had a very small (about 5%) pearl millet component. I suggest that during the next phase of this project (2000-2001) we expand efforts in this area in order to introduce a wide range of high-biomass populations, open-pollinated varieties, hybrid seed parents, and hybrid restorer lines in a range of plant heights, maturities, tillering abilities, and grain types. Following their safe introduction and quarantine clearance, these materials can be evaluated for the following:

- high biomass yield potential and low photoperiodsensitivity;
- tolerance to acid-soils (high Al^{3+} saturation);
- tolerance to low phosphorus availability; and,
- resistance to foliar diseases, especially rust, caused by *Puccinia substriata* Ellis & Barth. Var. indica Ramachar & Cummins (syn. P. *penniseti Zimm.),* which is already assuming some importance in the *Cerrados* region of Brazil.

Scope of Phase III pearl millet activities

This collaboration should emphasize:

- assisting national sorghum programs in Latin America,
- training (at ICRISAT, Patancheru) of selected pearl millet improvement scientists from the region (e.g., Alfonso Gonzalez of CORPOICA),
- identification of sources and screening methods to improve levels of foliar disease resistance to address the major researchable biotic constraints to pearl millet biomass production and forage quality in the region, and,
- while introducing and evaluating hybrid parental lines, the major focus of the initial work should be open-pollinated genotypes (synthetics and composites).

Project partners and contacts

The institutions that could most actively participate in this project, and the contact persons in each are as follows:

- CORPOICA. Jaime Bernal
- CNPMS/EMBRAPA. Bob Schaffert, Fredolino Santos, and Dea Martins Netto
- FONAIAP
- ICRISAT. Tom Hash, Belum VS. Reddy, and Andres Rangel
- CLAT. Richard Thomas, John Miles, and Hernan Ceballos.

  The participation of additional national programs from the region would be most welcome.

Seasons available for seed multiplication and evaluation

As in the current project, we can expect to make substantial progress by using three seasons each year for seed multiplication and evaluation:

- January/February: Off-season activities (primarily seed multiplication) at CIAT-Palmira,
- May/June sowings: Evaluate for acid-soil tolerance + foliar disease resistance by field screening in the *llanos,* and,
- September/October sowings: Evaluate for acid-soil tolerance + terminal drought stress tolerance by field screening in the *llanos.*

Conclusion

That completes my outline of the proposed expansion of collaborative pearl millet improvement research activities in the region. The discussion session that follows provides us an opportunity for frank and open scientific exchange among current and potential partners in this activity. Most importantly, we need your input in deciding an appropriate level of investment in pearl millet vis-a-vis sorghum. I find the current level of investment in pearl millet (about 5% of project resources) to be too small, but if that is the level of investment that national programs in the region prefer, then ICRISAT will be glad to seek continuation of current levels of funding. If more resources are to be invested in pearl millet research in this region, we will also need your suggestions as to whether this should come at the expense of sorghum research (i.e., keep total investment in sorghum and pearl millet at current levels) or whether ICRISAT should be seeking additional support in order to expand the pearl millet component of the program. This meeting has also provided you opportunities to monitor progress to date from this project's limited investments in pearl millet, including demonstration of performance of genetic materials in the field at two sites here in the Colombian acid-soil savannas.

Individual Sessions Chairs' Reports

Session II: Collaborators' Reports

Session Chair: **Dr. Jaime H. Bernal**
Reporter: **Ing. Andre's Felipe Rangel**

Dr. Gillson E. V. Pitta (EMBRAPA) presented

Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA): A broad view

Dr Pitta briefly described the work done by EMBRAPA mainly in the *Cerrados* zone, focusing on their approach to generating technology for this region, which is characterized by constraints like soil acidity and other abiotic stresses.

Exchangeable Al^{3+} is one of the main problems in acid soils and this factor determined the research groups at EMBRAPA in crops like sorghum, pearl millet, and maize. These groups basically identified acid-tolerant and phosphate and nitrogen-efficient plant genotypes. They also identified some of the mechanisms that determined such tolerance.

Dr. Fredolino G.dos Santos, (EMBRAPA) presented

Sorghum and pearl millet in Brazil: results and prospects

Dr Dos Santos presented the main objectives of the program, which focussed on development of inbred lines resistant to biotic constraints like anthracnose, sugarcane mosaic, fungus head bugs and birds (durine and tannin contents). Anthracnose resistance is aimed at in breeding high-yielding B-and R-lines. With regard to abiotic stresses, Al^{3+} and nutrient-efficient (especially N) genotypes, herbicide resistance and drought tolerance are the main goals. Drought tolerance is very important in the *Cerrados,* because 90% of the sorghum production follows the soybean crop, under conditions of severe drought. Population breeding was done on seven populations to identify lines.

The work resulted in the identification, release, and production of:

- BRP9R forage time
- BRP11BR B and R tolerant lines
- BR 300 high adaptation and intermediate maturity hybrid
- BR 303 high adaptation and Intermediate maturity hybrid
- BR 304 planted after soybean crop
- BR 305 tannin content and drought tolerant
- BR 306 planted after soybean crop
- Varieties for human consumption
- Five aluminium-tolerant forage sorghum hybrids

New projects involve evaluation of genetic management and development of a national network of research and transfer of technology, and the identification of new lines for grain and forage purpose through population breeding.

Dr. Ana Rita Brito (IPA) presented

Empresa Permambucana de Pesquisa Agropecuaria, IPA, general vision

Dr. Brito emphasized the importance of genetic breeding for animals and plants and their interaction with soil conditions in the northeast region of the *Cerrados* (almost 226,0153 km^2 more or less 15% of the total *Cerrados* in Brazil).

Dr. Pedro Jose Garcia, (FONAIAP) presented

Current status of Venezuelan research on grain sorghum cultivars tolerant to acid-soil conditions

Dr. Garcia explained the need to create a national sorghum and pearl millet program with adequate emphasis on acid-soils in Venezuela. Eighty percent of the sorghum production in Venezuela is obtained from the Central and Eastern *Llanos* under acidic, low-nutrient soils with medium Al^{3+} concentrations. He also mentioned birds as a major problem in sorghum production, and spoke on the need to develop acid-tolerant varieties and sorghum hybrids and to encourage pearl millet as a new crop in the region.

Drs Hector Sierra and Rafael A. Mateo (ZAMORANO) presented

Honduras Sorghum Project

Sorghum, the third most important crop in Central America, is produced mainly in the semi-arid zones and principally for human consumption. In 1997, sorghum grown on 283 000 ha produced 141 ha^{-1}. Sorghum production is realized by three different kinds of farmers in Central America: (a) Small or subsistence farmers (less than 3 ha) who cultivate 67% of the total area in Central America and use photosensitive sorghums; (b) Medium farmers (4 to 10 ha) who plant non-photosensitive sorghum and use some mechanized farming; and (c) Large farmers (more than 10 ha) who apply technology, sponsor research activities and control the market. This group uses hybrids, mainly for the concentrate industries.

The breeding program at ZAMORANO has been working on sorghum landraces, hybrid evaluation and entomology of sorghum. They had also been working on the transition from the cultivation of plantain to sorghum in the north zone of Honduras and its impact.

Dr. Jaime H Bernai, (CORPOICA) presented

Sorghum breeding for acid soils in Colombia

Acid soils in Colombia fall into the categories of Oxisols and Ultisols (57% of the extension); they mainly occupy the savannas system which is characterized by extensive cattle grazing. National research programs, CIAT and INTSORMIL in 1983 started a sorghum-breeding program for acid-soils in Colombia. The program evaluated and selected varieties and hybrids from INTSORMIL and ICRISAT in the region. The project finally released three varieties to the farmers: Real 40, Real 60 and Icaravan. Varieties that produced 0.8 to 3 t ha^1 were selected for different Al^{3+} saturations (between 30 and 90%).

Sorghum and pearl millet programs had attempted to increase the materials' efficiency (varieties and hybrids) to low and high inputs, development of forage types and the utilization of both crops in land-conservation practices.

Session III. Latin America Sorghum and Pearl Millet Network Project

Session Chair: **Dr. Gilson E. V. Pitta**
Reporter: **Ing. Luis A. Gonzalez**

Dr. Belum Reddy (ICRISAT) presented

Evaluation of sorghum and pearl millet for acid-soil tolerance in the oriental *Llanos* of Colombia

Dr Reddy described, as a project target, the adaptation of sorghum and pearl millet lines to the acid soils in the oriental *Llanos.* The introduction and evaluation of A, B and R lines of grain and forage sorghum inbred lines and populations initiated the studies in the program. A similar pattern was followed with pearl millet genotypes.

Four locations were previously selected: Quilichao (Cauca), La Libertad, Carimagua and Matazul (Meta), based on the differential Al-saturation levels. Two forage genotypes of sorghum were selected and classified as tolerant to aluminum: IS 31496 and IS 15868.

2. Genotype (G) x Environment (E) interactions in sorghum on acid soils of the oriental *Llanos* of Colombia

The program tested 64 R lines and 87 B lines along with 6 standard checks in each trial under three Al^{3+} saturation levels—40%, 60%, and 80%. The most contrasting grain yield production was observed with the 60% level. Studies are currently being carried out in parallel with the introductory and evaluation experiments. The locations are the same as those mentioned previously. These are part of the specific studies of the project.

One genotype of grain sorghum (IS 30469-1187-2) and one of forage sorghum (S 31496) were selected, considering 60% aluminum saturation as reference.

Drs. Jaime H Bernal and Ruben Valencia presented (CORPOICA)

Efficiency of two rapid-screening methods for aluminium tolerance in soybean (Cilycia max (L) genotypes

Dr.Bernal mentioned the two techniques used in the project; hematoxylin staining and nutrient solution using different concentrations of aluminum.

Dr. Valencia explained the mode of aluminum tolerance in soybean plants, and its effects at cellular level, principally in the cells of the roots. He also spoke on the relative importance of the presence of aluminum in the shoot as a criterion for the selection of tolerant genotypes.

The use of 250 M of Al^{3+} in nutrient solutions is now accepted as the critical concentration to select tolerant materials. Based on the results, three sorghum genotypes were selected; IS 7180, IS 7440, and IS 8577.

Field Visits

Session Chair: Dr. Belum V S Reddy

Two experimental areas were visited by the participants. These were:

- Network trials (sorghum male-sterile lines and restorer lines, and forage sorghum and pearl millet lines) which are at grand growth stage at La Libertad, CORPOICA farm,under acid-soil conditions. The tour was conducted by Jaime Bernal; and
- Network trials and breeding materials, being evaluated by ICRISAT/CIAT under acid-soil conditions at Matazul (a location about 130 km east of La Libertad);these materials are at maturity stage.

Nearly 25 participants visited the field experiments. At La Libertad, participants were impressed with the significant differences among sorghum genotypes for growth and establishment, and the excellent root and shoot growth of the pearlmillet lines. At Matazul, since the materials flowered early, the performance of the sorghum materials in relation to the late-maturing acid-soil control, Real 60, was not impressive. However, the hybrids made between the selected acid-soil tolerant parents, and some of the segregating sorghum progenies were quite impressive. The potential of pearl millet as a cover crop, the forage potential in two sorghum lines, and grain yield expression of sorghum hybrids were appreciated by the participants.

Session IV: Proposals and Future Plans

Session Chair: Dr. Fredolino G. dos Santos
Reporter: Dr. C.T. Hash

Ing. Andres Felipe Rangel, (ICRISAT/CIAT), presented

1.Latin American Network Trials: prospects and problems.

The objectives of the Project are: (a) to develop genotypes tolerant to acid soils, (b) To evaluate, and select materials and make them available for the trial network, and (c) to facilitate and encourage the exchange of the results.

The 1998 Network Program conducted 21 trials consisting of A, B and R grain sorghums and forage sorghum bred lines as well as pearl millet bred lines, and the major parameters recorded were: vigor, flowering date, agronomic performances, reaction to the principal diseases and grain yield and/or fresh weight potential.

The most tolerant genotypes, selected for acid conditions, were:

- Grain sorghum- SPA_2 94029, ICSB 93, ICSR 110
- Forage sorghum- IS 13868 (Sweet sorghum)
- Pearl millet- ICMV 93751, ICMP 92853, ICMS 7703

A brief mention was made about poor data returns

The program for 1999 comprises:

- Dispatch of trials to collaborators
- Evaluation of the promising genotypes tested in 1998
- Development of hybrids,
- Breeding of A/B and R-lines and populations,
- Publication of the proceedings of the workshop held in Villavicencio.

Dr. C.T. Hash, (ICRISAT), presented

2. Pearl Millet as a component of sustainable production in Latin America

In summary, Dr Hash pointed out the importance of pearl millet for small farmers, principally those of the semi-arid conditions where low fertility and water deficits are the main constraints. In Africa and India, millet is cultivated on 28 million hectares, compared to 2.5 million in America. He also mentioned the importance of the crop in no-tillage systems of the Central part in Brazil, where the biomass produced has been used to improve the soil conditions and as cattle feed.

For the year 2000/2001 the basic proposals are:

- Improvement for high grain yield potential in open-pollinated varieties and inbred lines with genetic variability for plant height, tillering performance and type of grain.
- Evaluation for high biomass yield potential of open-pollinated genotypes with lower photosensitivity, tolerance to high aluminum concentrations, efficient phosphorus utilization and tolerance to diseases, principally rust.

General Discussion and Recommendations

Belum V S Reddy[1]

The moderators presented summaries of the sessions. Mr. Andres F. Rangel summarized Session I where Dr Dario Leal gave an overview of the CORPOICA Research Program for the Oriental *Llanos* Region. Dr Gillson Pitta and Dr. Fredolino G dos Santos, in their report on the National Maize and Sorghum Research Center, indicated the potential of the *Cerrados* soils for sorghum and pearl millet production, for cattle feeding and soil-fertility improvement, principally with millet in "no-tillage systems".

Mrs. Ana R. Brito presented the Pernambuco State Research Organization, IPA, and its research program. The semi-arid conditions of the agricultural systems are the primary focus of its research program.

Mr. Pedro Jose Garcia from the FONAIAP presented the results of the trials and pointed out some problems with birds and soil acidity at Venezuela. Mr. Rafael A. Mateo, Mr. Hector Sierra and Dr. Jaime H. Bernal also presented research results of the current year.

Dr Gillson Pitta presented the summary of Session II, where Drs. Belum Reddy and Jaime H. Bernal gave their presentations. After discussing the various presentations, the group arrived at the following conclusions/recommendations.

- The project work produced high-yielding, acid-soil tolerant, grain sorghum male-sterile lines and restorer lines and high biomass forage sorghum and pearl millet lines; and the project activities were executed well on time.

- The project also established a network involving scientists from the member countries, including Honduras.

- The data returns from the network collaborators are below the expected level.Therefore,the group identified the budget as the main constraint and recommended that an amount up to US $ 500 for three network trials should be reimbursed upon production of complete data sets as described in the guidelines.

- The seeds within the network countries should be distributed through the country coordinators. Jaime Bernal for Colombia, Fredolino G Santos for Brazil, Pedro Garcia for Venezuela, and Rafael A. Mateo for Honduras were chosen as the country coordinators.

- The project funding ends by 1999. So the group requested ICRISAT and CIAT to take the initiative to write further proposals to extend the work for another 4 years;the following areas were agreed upon for inclusion in the proposal.

1. Senior scientist, International Crops Research Instute for the Semi-Arid Tropics (ICRISAT), Patancheru 502 324 Andhra Pradesh, India

- Research on both sorghum and pearl millet should be included for adaptation to acid-soil conditions; but the research emphasis should be increased to 30% from the present 10% in pearl millet.
- Assessment of biomass should be emphasized in different fertility conditions for forage sorghum and pearl millet
- Genetic variability for nutrient uptake efficiency should be assessed
- Attention should be paid to the quality and quantity of sorghum and pearl millet grain and to semi-compact panicle types in sorghum.
- Sugarcane borer resistance improvement in sorghum should be included.
- Research on earlyness and tolerance in sorghum should be included in the proposal.
- Tolerance to low temperatures at flowering and ergot avoidance mechanisms should be explored.
- Genotypic efficiency in pearl millet for erosion control and organicmatter enrichment to the soil should be part of the proposal.
- Genotypic efficiency in extracting the nutrients from deeper layers of soil should be a part of the proposal.

* Further, it was agreed that the exchange of sorghum and peral millet seeds between the collaborators should be based on each country's import regulations.

Closing Remarks

Belum V S.Reddy[1]

The workshop provided an opportunity for participants to learn from each other and share different perspectives. The efforts and enthusiasm of the participants in supporting the network should go a long way in capitalizing on the synergy of the collaborative effort. ICRISAT/CIAT should seek continued cooperation and support for the implementation of the project in the remaining period and in writing a new proposal to extend the work to other areas, including acid-soil tolerance.

The project was implemented with funding support from the Inter American Development Bank and this financial assistance is gratefully acknowledged. The authorities of CORPOICA, in particular Dr. Jaime Triana, Director, Region 8, Dr Dario Leal, Coordinator (Research), and Mr. Jaime Bernal, Physiologist gave us their unlimited support in conducting the workshop and we thank them profusely. The efforts and enthusiasm of the participants are appreciated. The encouragement given by Dr Paula Bramel Cox, Acting Director, Genetic Resources and Enhancement Program, the input of Dr.C.T Hash, Principal Scientist, ICRISAT, and the cooperation extended by Mr. Andres Felipe Rangel, Assistant Researcher, CIAT/ ICRISAT is duly acknowledged. The efforts of the Chairperson and moderators are gratefully acknowledged for encouraging the meaningful discussion and yet maintaining the time schedule

1. Senior scientist, International Crops Research Instute for the Semi-Arid Tropics (ICRISAT), Patancheru 502 324 Andhra Pradesh, India

Workshop Program

NARS/ICRISAT/CIAT

A Research and Network Strategy for Sustainable Sorghum and Pearl Millet Production Systems for Latin America

Corporaci6n Colombiana de Investigaci6n Agropecuaria (CORPOICA), Centro de Investigaciones "La Libertad", Villavicencio, Meta, 24-26 November, 1998

Monday, 23 November: Welcome and Registration

Arrival and registration of participants at "La Libertad," Experimental Center (CORPOICA)

Tuesday, 24 November: Registration

Session I: Inaugural Session

Permanent registration desk (8:00-9:45 am).

8:30 Dr. Jaime Jose Triana Restrepo, Director General, CORPOICA,Region 8. Welcome Remarks

8:45 Dr. Dario Leal M., Research Coordinator, CORPOICA, Region 8. A General Vision of CORPOICA Region 8 in the Eastern Plains of Colombia

9:15 Dr. C.T.Hash, Principal Scientist (Breeding), Pearl Millet Genetic Resources and Enhancement Program, ICRISAT A Research and Network Strategy for Sustainable Sorghum Production Systems for Latin America: Project Outline

9:45 Coffee

Session II: Collaborators' Reports

Session Chair: **Dr. Jaime H. Bernal**

Moderator: **Ing. Andres Felipe Rangel**

10:00 Dr. Gilson E. V. Pitta (EMBRAPA). Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA): General Vision

Dr. Fredolino G. dos Santos (EMBRAPA). Sorghum and Pearl Millet in Brazil: Results and Prospects

10:30 Dr. Ana Rita Brito (IPA). Sorghum and Pearl Millet Prospects in Pernambuco State (Brazil Northeast Region)

10:45 Dr. Pedro Josee Garcia (FONAIAP). Current Status of Venezuelan Research on Grain Sorghum Cultivars Tolerant to Acid-Soil Conditions

11:00 Dr. Hector Sierra (EAP, ZAMORANO). Honduras Sorghum Project

Dr. Rafael A. Mateo (EAP), ZAMORANO). Honduras Sorghum Project

11:30 Dr. Jaime H. Bernal (CORPOICA). Sorghum Breeding for Acid Soils in Colombia

11:45 Dr. German Escobar (CIAT). Prospects for Sorghum and Pearl Millet Utilization in Acid Soils in Cauca State

12:00 Lunch

Session III: Latin American Sorghum and Pearl Millet Network Project

Session Chair: **Dr. Gilson V Exel Pitta**
Moderator: **Ing. Luis A. Gonzalez**

2:00 **Dr. Beluni VS. Reddy (ICRISAT).** Evaluation of Sorghum and Pearl Millet for Acid-Soil Tolerance in the Oriental *Llanos* of Colombia

2:20 **Dr. Belum VS. Reddy (ICRISAT).** Genotype (G) and G x Environment (E) Interactions in Sorghum on Acid Soils of the Oriental *Llanos* of Colombia

2:45 Coffee

3:00 **Dr. Jaime H. Bernal and Ruben Valencia (CORPOICA)** Efficiency of Two (Merril) Genotypes

Wednesday, 25 November: Field Visits

Session Chair: **Dr. Belum VS. Reddy**
Moderator: **Ing Andres Felipe Rangel**

8:00 Meet at the main entrance

8:15 **Dr. Jaime H. Bernal (CORPOICA).** "La Libertad" Network Trials

9:30 Departure to Matazul

11:00 **Ing. Andres Felipe Rangel (ICRISAT/CIAT).** "Matazul" Network Trials and Breeding Nurseries

12:30 Lunch

2:00 Return to "La Libertad" Experimental Center

Thursday, 26 November: Plenary Session

Session IV: Proposals And Future Plans

Session Chair: **Dr. Fredolino G. dos Santos**
Moderator: **Dr. C. Tom Hash**

8:00 **Ing. Andres Felipe Rangel (ICRISAT/CIAT).** Network Trials-Prospects and Problems.

8:30 ***Dr.* Tom Hash (ICRISAT)**: Pearl Millet as a Component of Sustainable Production Systems in Latin America

9:00 Coffee

9:15 General Discussion and Conclusion

11:30 **Dr. Beluni V. S. Reddy (ICRISAT).** Acknowledgments and Closing Remarks

11:45 Lunch

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To be continued

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Acronyms and Abbreviations

ACIN	Indigenous Town Council Association of Northern Cauca, Colombia
CARDI	Caribbean Agricultural Research and Development Institute
CGIAR	Consultative Group on International Agricultural Research
CIAT	Centro International de Agricultura Tropical
CNPMS	Centro Nacional de Pesquisa de Milho e Sorgo
CORPOICA	Corporaci6n Colombiana de Investigacion Agropecuaria
EAP	Escuela Agricola Panamericana
EMBRAPA	Empresa Brasiliera de Pesquisa Agropecuaria
FONAIAP	Fondo Nacional de Investigaciones Agropecuarias (Venezuela)
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ICA	Institute Colombiana Agropecuaria
IDB	Inter-American Development Bank
INTSORMIL	International Sorghum and Pearl Millet Program
IPA	Empresa Pernambucana De pesquisa Agropecuria
NARS	National Agricultural Research System
PRONATTA	Programa Nacional de Transferencia de Tecnologia Agropecuaria
USDA	United States Department of Agriculture

Workshop on Research and Network Strategy for Sustainable Sorghum and Pearl Millet Production Systems for Latin America

24–26 November 1998, Experimental Center "La Libertad", Villavicencio, Colombia

Notes

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RA-00351

About ICRISAT

The semi-arid tropics (SAT) encompasses parts of 48 developing countries including most of India, parts of southeast Asia, a swathe across sub-Saharan Africa, much of southern and eastern Africa, and parts of Latin America. Many of these countries are among the poorest in the world. Approximately one-sixth of the world's population lives in the SAT, which is typified by unpredictable weather, limited and erratic rainfall, and nutrient-poor soils.

ICRISAT's mandate crops are sorghum, pearl millet, finger millet, chickpea, pigeonpea, and groundnut; these six crops are vital to life for the ever-increasing populations of the semi-arid tropics. ICRISAT's mission is to conduct research which can lead to enhanced sustainable production of these crops and to improved management of the limited natural resources of the SAT. ICRISAT communicates information on technologies as they are developed through workshops, networks, training, library services, and publishing.

ICRISAT was established in 1972. It is one of 16 nonprofit, research and training centers funded through the Consultative Group on International Agricultural Research (CGIAR). The CGIAR is an informal association of approximately 50 public and private sector donors; it is co-sponsored by the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP), and the World Bank.

About CIAT

The International Center for Tropical Agriculture (CIAT, its Spanish acronym) is dedicated to the alleviation of hunger and poverty in developing countries of the tropics. CIAT applies science to agriculture to increase food production while sustaining the natural resource base.

CIAT is one of 16 international agricultural research centers sponsored by the Consultative Group on International Agricultural Research (CGIAR).

The Center's core budget is financed by 28 donor countries, international and regional development organizations, and private foundations. In 1999, the donor countries included Austrialia, Belgium, Brazil, Canada, Colombia, New Zealand, Norway, South Africa, Spain, Sweden, Switzerland, the United Kingdom, and the United States of America. Donor organizations include the European Union (EU), the Food and Agriculture Organization of the United Nations (FAO), the Ford Foundation, the Inter-American Development Bank (IDB), the International Development Research Center (IDRC), International Fund for Agricultural Development (IFAD), the Rockefeller Foundation, and the World Bank.

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