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SAHEL REGIONAL AID PLANNING AND COORDINATION
END-OF-CONTRACT STATEMENT

Contract No. AFR-0929-G-SS-1104-00

Project No. 32-2445-001

Advisory Committee on the Sahel
Board on Science and Technology for International Development
Office of International Affairs

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NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the Councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to the procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

This end-of-contract statement has been prepared by the staff of the Advisory Committee on the Sahel, Board on Science and Technology for International Development, National Research Council, for the Office of Sahel Regional Aid Planning and Coordination, Agency for International Development, Washington, D.C., under contract No. AFR-0929-G-SS-1104-00.

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EXECUTIVE SUMMARY

The program of the Advisory Committee on the Sahel (ACOS) of the National Research Council (NRC) was initiated in May 1978. It is administered by the NRC's Board on Science and Technology for International Development (BOSTID). Under this program, the ACOS has worked with the Agency for International Development (AID), Sahelian governments, regional organizations, and other bodies active in the Sahel region to reconcile conservation needs with development objectives. In doing so, the ACOS has stressed the need to restore and maintain the ecosystems that support the livelihood of Sahelian populations, to restore and preserve the genetic diversity necessary to stabilize Sahelian ecosystems and increase economic opportunity, and to ensure the sustainable utilization of ecosystems and the many plant and animal species that support rural populations.

This report covers the second phase of the ACOS program, an 18-month period beginning September 15, 1981, and ending March 15, 1983. (A no-cost extension of the grant will enable the program to continue through June 30, 1983). The activities undertaken during this period were supported by a $285,000 grant from AID's Office of Sahel and West African Affairs. Supplemental funds were made available by the Australian Development Assistance Bureau (ADAB) for the purchase of Australian seed included in the ACOS species trials. The program was directed by an advisory committee composed of five scientists and was implemented by BOSTID staff members, Jeffrey Gritzner and Carol Corillon. The committee met three times during the grant period: May 27, 1982; August 5-6, 1982; and February 2-3, 1983. Individual ACOS members accepted special responsibility for various aspects of the program, and along with a diverse group of other individuals and organizations, were consulted throughout the course of the grant by the BOSTID staff.

The publications, the research efforts, the institution-building activities, and the scientific networking contacts made during the course of the grant were undertaken in response to interest shown, or requests made, by AID/Washington and AID missions in the Sahel and in consideration of the interests and needs of Sahelian governments and development organizations.

Although the activities undertaken during the period of the grant are described in detail later in this statement, the major areas of the program are described briefly below:

1. Publication: Environmental Change in the West African Sahel

An inadequate understanding of Sahelian climatology, environmental history, and ecosystem function has hindered the formulation and successful implementation of environmental and agricultural projects in the Sahel. In this study, the ACOS has attempted to gain a better understanding of ecological processes and their relationship to degradation and rehabilitation in the Sahel and provide baseline information for the formulation of environmentally sound development projects.

Analysis of stream deposits, fossil sands, and lake beds reveals that little significant climatic change has occurred in the Sahel during the last 2,500 years. The physical record, combined with the historical, describes a highly variable Sahelian climatic regime in which unevenly distributed rainfall and drought are "normal." Further analysis reveals that human activity is the principal cause of environmental degradation in the Sahel. In addition to the well-documented impacts of modern livestock programs, agricultural expansion, and other recent activities, ancient practices such as setting bush fires, charcoal production in connection with the trans-Saharan trade and iron smelting, and the establishment of settlements on easily destabilized sites have progressively decreased the diversity and resiliency of Sahelian ecosystems.

The report concludes that development efforts can and should be better reconciled with environmental processes. Cattle, for example, are poorly adapted to Sahelian conditions, and many better adapted, locally preferred forms of livestock such as goats and camels have been neglected in regional animal husbandry programs. Similarly, efforts should be made to diversify and stabilize agricultural systems through the systematic introduction of environmentally and economically beneficial trees and shrubs. The dynamic components of environmental systems, such as wind, water, and animal movement can be better incorporated into projects in order to facilitate seed dispersal and promote revegetation (see Figure 1).

2. Formal and Informal Species Trials

To restore biological diversity in the Sahel, the ACOS has identified species of trees, shrubs, grasses, and drought-tolerant food crops that could prove appropriate for environmental rehabilitation, range improvement, and agriculture projects in the Sahel. Over 180 accessions of such species were obtained by BOSTID from arid zones around the world and distributed to plant scientists working in the Sahel or in analogous regions elsewhere for formal and informal testing.

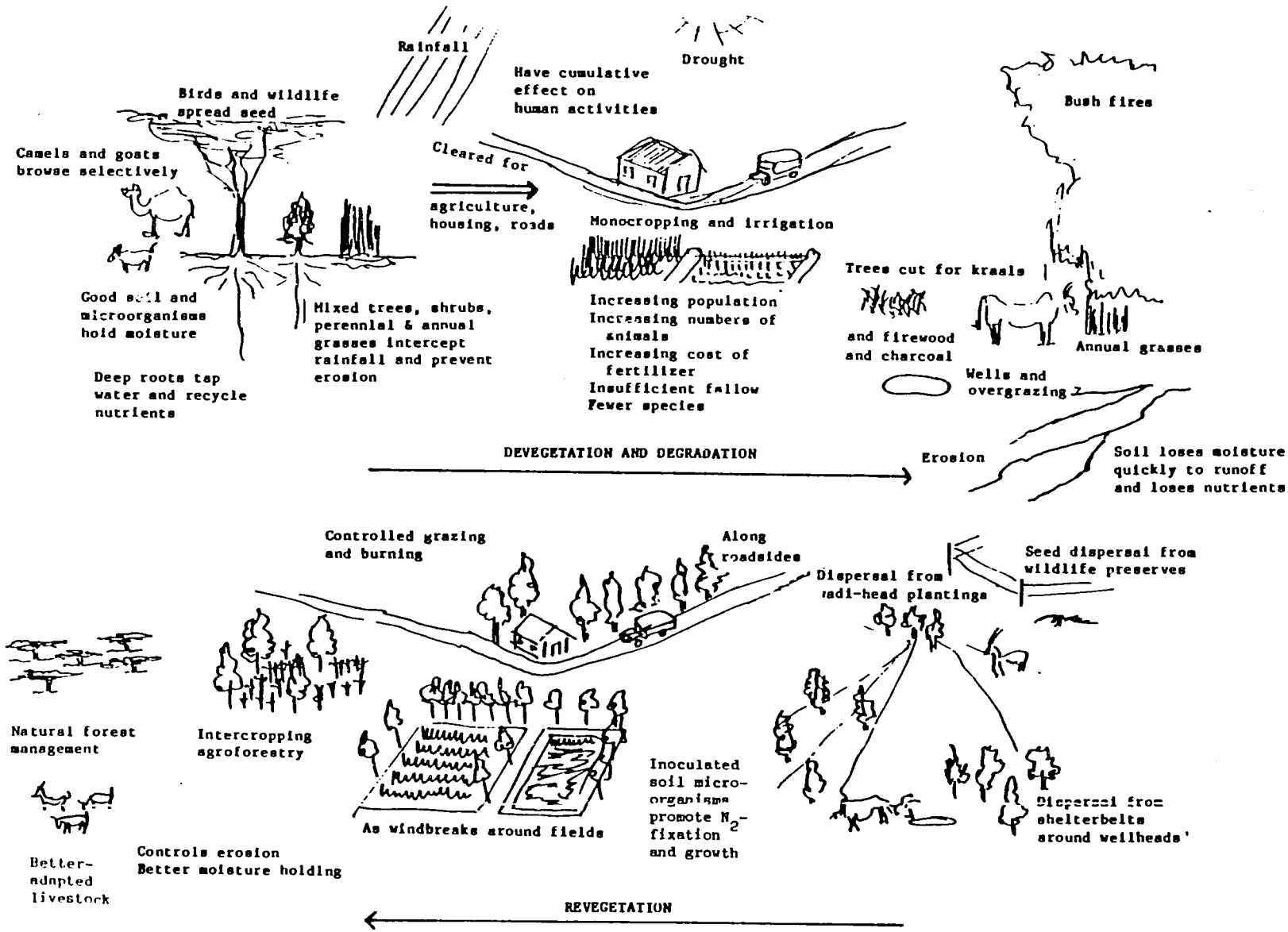
Rainfall
Drought
Have cumulative effect on human activities
Birds and wildlife spread seed
Bush fires
Camels and goats browse selectively
Cleared for
agriculture, housing, roads
Monocropping and irrigation
Trees cut for kraals
Good soil and microorganisms hold moisture
Mixed trees, shrubs, perennial & annual grasses intercept rainfall and prevent erosion
Increasing population
Increasing numbers of animals
Increasing cost of fertilizer
Insufficient fallow
Fewer species
and firewood and charcoal
Annual grasses
Wells and overgrazing
Deep roots tap water and recycle nutrients
DEVEGETATION AND DEGRADATION
Erosion
Soil loses moisture quickly to runoff and loses nutrients
Controlled grazing and burning
Along roadsides
Dispersal from wadi-head plantings
Seed dispersal from wildlife preserves
Natural forest management
Intercropping agroforestry
As windbreaks around fields
Inoculated soil micro-organisms promote N_2-fixation and growth
Dispersal from shelterbelts around wellheads
Better-adapted livestock
Controls erosion
Better moisture holding
REVEGETATION
Through both strengthened natural mechanisms and by planting trees and shrubs in strategic locations
Species trials to determine appropriate species for shelterbelts, living fences, agroforestry, sand stabilization, etc.

FIGURE 1

Evaluation forms sent by ACOS to all participating researchers were completed by many and returned with comments and recommendations. The formal trials, which are testing 20 accessions of leguminous trees in the lower rainfall region of the Sahel, represent an effort to relate performance to site variables such as soil factors, rainfall and temperature.

3. Publication: Agroforestry in the West African Sahel

"Agroforestry" is a new word for the centuries-old traditional Sahelian practice, sadly neglected in recent decades, of growing woody plants with agricultural crops and/or livestock together on the same land. In modern-day application, these traditional practices should be combined with new strategies and technologies to put the many components of agroforestry to the best possible use in the limited space available. Agroforestry offers an alternative to the agriculture and livestock production systems that are currently contributing to degradation in the Sahel. While more research is needed, particularly in the area of crop compatibility, the multiple benefits and greater stability of agroforestry systems make them particularly attractive in regions of high climatic variability such as the Sahel. In addition to providing a broader range of economic products such as food, fuel, fodder, construction materials, and various tertiary products, the trees and shrubs incorporated into agroforestry systems increase wildlife habitat, recycle critical nutrients such as nitrogen, facilitate groundwater recharge, and perform other important ecological functions. The report provides development planners with information regarding traditional systems of agroforestry, its relevance to the modern Sahel, the design of agroforestry systems, social and institutional considerations, and criteria for the selection of appropriate plant species to be used.

4. Scientific Networking

To reinforce development activities and to strengthen regional institutions such as the Sahel Institute, ACOS has maintained close contact with numerous Sahel-related organizations including the AID-sponsored Environmental Training and Management in Africa program, the Sahel Institute, Peace Corps, the United Nations Educational, Scientific, and Cultural Organization (UNESCO), the Food and Agriculture Organization of the United Nations (FAO), the International Union for Conservation of Nature and Natural Resources (IUCN), the World Bank, and others. These organizations have been briefed on ACOS activities, scientific information has been exchanged, and, when requested, ACOS has made recommendations on their environmental activities. ACOS has also informed each group about activities of the others to promote complementarity and has participated in international meetings relating to the Sahel region.

An approximate distribution of program costs appear below. Estimates include salaries and wages (professional, secretarial/clerical), fringe benefits, overhead, travel and transportation, other direct costs, and general and administrative costs.

Program Element	Approximate Cost
Environmental change	$ 43,954
Species trials	74,159
Agroforestry	43,948
Scientific networking	39,568
MIRCEN	39,935
Program administration	43,436
TOTAL	$285,000

5. Establishment of a West African Microbiological Resources Center (MIRCEN) in Senegal

Tests done on cleared Sahelian soils, in areas where leguminous species were previously established, have revealed that Rhizobium spp. are frequently not present. (Rhizobia are nitrogen-fixing bacteria found in the roots of certain legumes such as cowpeas and acacia trees.) To counteract the nitrogen deficiency commonly found in Sahelian soils, plants can be inoculated with rhizobial bacteria, enabling them to use atmospheric nitrogen to build protein. This technique is less expensive and more environmentally acceptable than the use of commercial nitrogen fertilizer.

To make rhizobia and other soil microbial factors available to the Sahelian countries, ACOS acted as the lead organization in the establishment of a Microbiological Resources Center (MIRCEN) at an existing research center in Bambey, Senegal, as a West African member of an international network of MIRCENs. A number of international donor organizations were involved in the project formulation and implementation. A Senegalese technical director now heads the MIRCEN program, and a consultant from Agriculture Canada has agreed to make periodic visits to the laboratory to assist its development. This consultant's salary was obtained by ACOS from the Foundation for Microbiology in New York. The MIRCEN will be used to select, collect, multiply, and distribute rhizobial strains and to organize training programs in biological nitrogen fixation for the West African region.

INTRODUCTION

The Sahel program of the National Research Council (NRC) began in 1973 with the formation of the Advisory Panel on Arid Lands of Sub-Saharan Africa. The panel, administered by the NRC's Board on Science and Technology for International Development (BOSTID), was established at the request of the Agency for International Development (AID) to ". . . advise AID with respect to the critical medium- and long-term natural resources management problems of the drought-stricken region of West Africa, and to provide assistance in the design and implementation of U.S. participation in an international collaborative scientific effort being organized to address the emergency situation." Among its activities, the panel and the Rockefeller Foundation cosponsored the Conference on International Development Strategies for the Sahel, held at Bellagio, Italy, in 1974. The principal conclusions and recommendations of the panel are contained in a three-volume report released by the National Academy of Sciences in 1975 and in the Rockefeller Foundation working papers describing the Bellagio conference. A summary of the conclusions and recommendations is contained in the appended letter from panel chairman John McKelvey, Jr., to George Hammond, Foreign Secretary of the National Academy of Sciences and Chairman of the NRC's Commission on International Relations (see Appendix A).

The panel also recommended that BOSTID continue to assist AID with the agency's efforts in the Sahel region. At AID's request, the Advisory Committee on the Sahel (ACOS) was organized in 1978 to formulate a long-term strategy for environmental rehabilitation and development in the Sahel.

The ACOS has worked to gain a better understanding of ecological processes and their relationship to degradation and rehabilitation in the Sahel region. It has studied both long-term environmental change in the region and man's role in modifying Sahelian ecosystems. It has also worked to develop sound approaches to project identification, such as the analysis of the normal transformations and sequential dependencies of energy flow within ecosystems, in order to determine where ecosystem functions have broken down, and to recommend measures to systematically restore environmental systems. The reintroduction of critical soil microorganisms (such as nitrogen-fixing rhizobia) in degraded areas, soil conservation, groundwater recharge, and the

restoration of greater biological diversity have been emphasized. Increased stability and productivity of Sahelian agro-silvo-pastoral systems will better assure availability of the food, fuel, fodder, and other commodities necessary to promote the self-reliance of Sahelian populations.

ACOS ACTIVITIES UNDER CURRENT GRANT

1. Publication: Environmental Change in the West African Sahel

Contractual Statement of Responsibility

> "A report will be published on the history of environmental change in the Sahel which will provide and assess baseline information on the nature and dynamics of Sahelian environments and outline recommendations to AID and other donors on scientific approaches to employ for targeting appropriate development interventions."

Background

An inadequate understanding of Sahelian climatology, environmental history, and ecosystem function has consistently hindered the formulation and successful implementation of environmental and agricultural projects in the Sahel. This has resulted in the misapplication of millions of dollars in donor assistance and in the growing vulnerability of Sahelian populations to economic adversity and natural hazards. Unless a realistic, process-oriented framework for action is identified, AID and other donors will be involved in a costly and endless search for more and more basic data. This study clarifies the environmental history of the region and provides baseline information for the formulation of projects to rehabilitate Sahelian ecosystems and promote sustainable agricultural and livestock production.

In the conclusions of research undertaken at the State University of New York at Buffalo and at the University of Chicago social and political instability in the Sahel was linked with deteriorating economic conditions which, in turn, largely reflect the instability and declining productivity of Sahelian agro-silvo-pastoral systems. Opportunities to undertake constructive development programs dependent on long-term institutional support may well be diminishing.

Activity Summary

A paleoenvironmental review and historical analysis were undertaken to assess the nature of environmental change in the Sahel: The long-term characteristics of the region were determined by examining the evidence provided by stream deposits, fossil sands, and lake beds and their related, abandoned shorelines. This evidence generally reveals that little significant long-term climatic change has occurred in the Sahel during the last 2,500 years.

The chronicles of medieval geographers and historians, the journals of early European travelers, the archaeological record, and other sources reveal that rainfall in the Sahel is generally low, unevenly distributed, and highly variable. Drought is an inherent feature of the region. These records indicate that major droughts, persisting for 12-15 years, evidently occurred in the 1680s, the mid-1700s, in the 1820s and 1830s, the 1910s, and since 1968. Generally arid conditions characterized the period from 1790 through 1850, and comparatively minor droughts apparently occurred in the 1640s, 1710s, 1810s, the beginning of the twentieth century, and the 1940s. Relatively wet periods occurred during the ninth through thirteenth centuries, the sixteenth through eighteenth centuries, from 1870 to 1895, and during the 1950s. In all development planning in the Sahel, high levels of climatic variability and inevitable drought should be accepted as being "normal."

In examining the impact of human activity on Sahelian ecosystems, it has become evident that man's role in transforming the region's environment has been significantly underestimated. Ancient and medieval societies had a substantial impact through activities such as setting bush fires, producing charcoal for local needs, and in connection with trans-Saharan trade, iron smelting, and the establishment of settlements on easily destabilized sites.

In modern times, many of these same activities, often on a larger scale, as well as activities associated with development and modernization, have caused further environmental degradation. The recent shift from camel nomadism to cattle rearing in the northern Sahelian rangelands has been particularly destructive, as the ecological shift from heterogeneous wooded steppe to highly simplified grass steppe, caused in large measure by bush fires, has rendered the region highly vulnerable to overgrazing. There was a five-fold increase in cattle in the Sahel during the 25 years preceding the 1968 drought. Unlike browsing livestock such as camels and goats, cattle are primarily grazers and therefore greatly increase pressure on climax perennial grasses, often resulting in their elimination or replacement by less nutritious annual grasses.

Nutrient cycling in Sahelian ecosystems is largely dependent on the presence of deep-rooted trees and shrubs. Hence, nutrient availability to support biological activity has been sharply reduced with the loss of woody perennials. Furthermore, the reduction or elimination of late dry-season grass cover has permitted additional degradation to occur with the arrival of the rainy season: raindrops striking an exposed, wet soil surface raise mud spatters, first sealing

the surface and then mobilizing soil particles small enough to be moved by overland water flow. This results both in reduced moisture infiltration leading to lowered groundwater tables and in soil erosion. The absence of cover further results in the loss of many critical soil organisms, such as nitrogen-fixing rhizobial bacteria. Cattle are also among the victims of this degradation. Cattle are not well adapted to Sahelian conditions, because their conversion efficiency is poor, they require substantial quantities of water, and they are highly subject to stress. Widespread environmental degradation renders them even more vulnerable.

Overhunting and direct competition with livestock have dramatically reduced wildlife populations in the Sahel. Birds and browsing herbivores formerly played critical roles in stimulating growth and dispersing seed of Sahelian trees and shrubs, prominently including large-seeded legumes such as Acacia, Albizzia, Bauhinia, Cassia, Entada, Parkia, Prosopis, Tetrapleura, and related genera. The dormancy of the seed consumed by the birds and animals is broken as it passes through their digestive tracts, and this process is often essential for germination. Domesticated livestock, particularly goats, can play a similarly important role in seed dispersal if properly managed.

The urgency of actively combating devegetation in the Sahel cannot be overstated. For example, it is believed by many scientists that devegetation caused by human activity can modify rainfall and prolong drought through "bio-geophysical feedback," a process through which devegetation increases surface albedo which, in turn, affects the atmospheric energy budget and promotes aridity. Aridity, in turn, affects productivity in virtually all economic sectors. It is also evident that degradation, once begun, acquires a certain momentum through feedback mechanisms. As restoring the stability of ecosystems is a costly, long-term process, the conservation of existing natural resources is critically important.

A more complete knowledge of Sahelian environments and the historical impact of human activity on Sahelian ecosystems gives development planners an understanding of the nature, causes, and spatial extent of environmental degradation. This knowledge permits planners to better assess the biological potential of the Sahel and identify specific measures that would help restore essential ecological processes and contribute to the development of more stable and productive agro-silvo-pastoral systems. It also helps planners to distinguish between destructive and environmentally sound activities in the Sahel and to combine historical analysis with modern ecological knowledge to develop useful guidelines for project design. For example, energy-flow models could be used to determine where ecosystem functions have broken down and identify measures to restore essential processes. Finally, because the activities of contemporary rural populations frequently contribute to environmental degradation, it is often possible to define site-specific projects at the village level in which these same populations can counter degradation through their involvement in the establishment of shelterbelts, revegetation of destabilized dunes, and similar measures.

Principal Contributors

The principal contributors to this study were Edmond Bernus of the Office de la Recherche Scientifique et Technique Outre-Mer (ORSTOM), Leonard Berry of Clark University, Karl Butzer of the University of Chicago, Robert Fishwick of the World Bank, agricultural consultant Francis LeBeau, Sharon Nicholson of Clark University, Wolf Roder of the University of Cincinnati, and Fred Weber of International Resources Development and Conservation Services. Other individuals who reviewed or otherwise contributed to this report include George Taylor II and Dayton Maxwell of AID, who helped relate the report to AID needs, Jean Maley of ORSTOM, Michael Watts of the University of California at Berkeley, F. Kenneth Hare of the University of Toronto, and William Clark of the Institute for Energy Analysis.

Recommended Future Activities

- Assist with the establishment in the Sahel of a project analogous to UNESCO's Integrated Project in Arid Lands (IPAL) in Kenya, to encourage coordinated research into the causes and effects of desertification in the Sahel. It is proposed that the project be associated institutionally with the Sahel Institute in Bamako, Mali. Systematic approaches to project identification, such as the energy-flow models, would be developed and tested.

- Promote research and experimentation in large-scale environmental rehabilitation--to facilitate seed dispersal and generally reinforce natural regenerative processes. For example, wadi-head plantings would result in seed being washed into and through wadi systems, thereby increasing vegetative cover along wadi courses. As attested by studies in the American Southwest, this can create extensive networks of vegetation available for further dispersal into adjacent areas. Projects should also be designed to better exploit livestock and wildlife movement, seasonally dominant northeasterly winds, and other environmental forces that promote seed dispersal and revegetation. By current project standards, such measures would be highly cost effective and could be complementary to other approaches to large-scale land rehabilitation, such as aerial seeding.

- Hold a seminar to determine the relevance of the ancient hema system of range reserves to pastureland management in sub-Saharan Africa. A serious obstacle to environmental rehabilitation and sustainable livestock production in the African drylands has been that governments and herders have not cooperated to develop pastoral systems that are both environmentally sound and economically viable. Such cooperation has successfully taken place in Saudi Arabia and in Syria through the revival of the ancient hema system, a system that incorporates conservation measures, such as range reserves and controlled grazing, with the

establishment of herder cooperatives. In hema systems, cooperative rangelands are allocated (often on the basis of traditional claims) and grazing is prohibited except for the herds owned by the cooperatives members. With regard to the potential contributions of these systems to environmental rehabilitation, it is noteworthy that hema cooperatives have been responsible for the revegetation of some 7 million hectares of rangeland in the Syrian steppes.

- Convene a panel on the reclamation and utilization of saline environments to study and make recommendations on the problem of expanding saline environments in the Sahel. Using information from preliminary studies already undertaken in the Fatik region of Senegal, selected scientists and Senegalese officials would meet in the field and recommend specific measures that would contribute to mangrove regeneration; the introduction of better adapted trees, shrubs, food crops, and browse species; fisheries improvement; and other interventions necessary to increase the productivity and stability of the region. Trials involving promising species would be designed and initiated during the activity.

- Organize a demonstration of sand-dune stabilization and utilization to support local efforts in dune stabilization. The demonstration would discuss the problems of wind-blown sand, provide a field demonstration of techniques in dune stabilization, consider the social aspects of successful dune stabilization efforts, and acquaint participants with activities necessary to support dune stabilization projects, such as nursery establishment and management. Special attention will be given to the use of tree and shrub species of economic value, such as Acacia senegal (gum arabic), in stabilization projects. The impact of this project would be significantly increased through the production of a training film on dune stabilization and the publication of a manual describing basic procedures for stabilization.

2. Formal and Informal Species Trials Involving Drought-Tolerant Trees, Shrubs, Grasses, and Food Crops

Contractual Statement of Responsibility

"In cooperation with Sahelian governments and international donors, appropriate trees, shrubs, and drought tolerant food crops will be identified which are best suited for Sahelian conditions."

Background

Analyses of the palynological record and botanical surveys indicate that Sahelian ecosystems have been dramatically modified through time.

Both the spatial extent of vegetative cover and biological diversity have been substantially reduced. Ecosystems "renew" themselves only as long as sufficient species diversity is maintained to prevent the collapse of the system. Beyond a certain threshold there is a dramatic "domino effect" to species loss within an ecosystem, leading to its collapse or radical simplification. Furthermore, the increasing loss of species may ultimately threaten the adaptive and evolutionary capabilities of plant and animal species, including man. In addition to reduced biological productivity and species extinctions, the collapse or simplification of Sahelian ecosystems has resulted in the declining viability of Sahelian agro-silvo-pastoral systems and a possible reduction of rainfall through bio-geophysical feedback mechanisms regulated by vegetative cover.

An initial ACOS response to this problem was the promotion of species trials to broaden the range of well-adapted native and exotic plant species to be included in conservation and development projects in the Sahel. The need for such trials was confirmed by President Jawara of The Gambia in discussions with ACOS staff in 1978. Dr. Jawara, at the time serving also as president of the Permanent Interstate Committee for Drought Control in the Sahel (CILSS), was particularly concerned by the relatively small number of tree species being included, or considered for inclusion, in Sahelian forestry projects. His concerns were echoed in subsequent meetings with Senegalese foresters. Early in 1979, President Senghor of Senegal announced the proposed diversification of agriculture in Senegal, an announcement that further stimulated interest in identifying well-adapted trees, shrubs, and "new crops" for rural development.

ACOS proposed a workshop on species selection to be held in Senegal in cooperation with the Senegalese Forest Service and AID in the spring of 1979. At the recommendation of Jean Gorse of the World Bank, and with the concurrence of El-Hadji Sène of the Senegalese Forest Service, the proposed workshop was divided into two "packages": one dealing with species appropriate for urban plantations, with particular reference to the needs of AID's Senegal Fuelwood Production Project (685-0219); the other concerned with trees, shrubs, and food crops appropriate for the development or restoration of agroforestry systems in rural areas. As the AID mission in Senegal was unable to participate in the workshop, the activity was shifted to Mauritania at the request of AID Representative Robert Klein and was held in April 1979. The workshop is described in the ACOS report, An Assessment of Agro-Forestry Potential Within the Environmental Framework of Mauritania.

Seed for trial plantings was distributed by the ACOS team to interested Mauritanian and donor officials. Subsequent requests for additional seed, and ACOS access to seed for drought-tolerant species through the international BOSTID network of plant scientists, led to ACOS support for informal species trials throughout the Sahel region. However, little information was generated regarding the relationship of plant performance to site variables, and no provision had been made for the systematic collection and discemination of trial data.

Activity Summary

On the basis of the experience gained during the first phase of the ACOS program and continuing AID interest in species evaluation, ACOS continued its efforts with better researched, more highly structured trials. An ACOS staff study was undertaken to relate species identification more precisely to the needs of environmental rehabilitation, range improvement, and agricultural projects in the Sahel. Because of the severe ecological and economic consequences of devegetation in the northern Sahel, and because very little research has been undertaken in this zone, a decision was made to concentrate on species associated with areas of low (100-500 mm, or 4-20 inches), variable rainfall in tropical desert (BWh) and tropical steppe (BSHw) climatic regions.

A list of 105 such species was drawn up and distributed to plant scientists familiar with the Sahel or with analogous regions elsewhere. These individuals were asked to evaluate the species with regard to the needs of the Sahel and to distribute the list further to qualified scientists not included in the initial mailing. Comments and recommendations were received from the following individuals:

M. Aydemir	Food and Agriculture Organization of the United Nations (FAO), Cape Verde
C. W. Barney	Forest and Wood Sciences, Colorado State University
Botanist-in-Charge	East African Herbarium
J. Burley	Commonwealth Forestry Institute, University of Oxford
R. Dinges	Texas Department of Health
P. Felker	Caesar Kleberg Wildlife Research Institute, Texas A&I University
P. Ffolliott	School of Renewable Natural Resources, University of Arizona
R. Fishwick	World Bank, Washington
C. Geerling	Nature Conservation Department, Agricultural University, Wageningen, Netherlands
J. Gorse	World Bank, Washington
M. Goumandakoye	Forest Service, Niger
A. Hall	Bolus Herbarium, University of Cape Town

O. Hamel	Senegalese Center for Forestry Research
J. Heermans	AID, Niger
H. N. le Houérou	FAO, Libya
F. Huxley	International Council for Research in Agroforestry (ICRAF), Kenya
R. N. Kaul	Forest Research Institute and Colleges, Dehra Dun, India
J. D. Keita	FAO, Ghana
H.-J. von Maydell	Institute for World Forestry, Hamburg, West Germany
F. Owino	Forestry Department, University of Nairobi
R. Pellek	AID, Cape Verde
J. F. Redhead	Faculty of Agriculture, Forestry, and Veterinary Sciences, University of Dar es Salaam
R. Reid	Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia
B. ben Salem	FAO, Rome
S. Seefeldt	AID, Mauritania
El-Hadji Sène	Senegalese Forest Service
G. Taylor	AID/SDPT, Mali
D. Webb	International Development Research Centre (IDRC), Senegal
F. Weber	International Resources Development and Conservation Services
G. White	USDA, Beltsville
P. Wood	Commonwealth Forestry Institute, University of Oxford
M. Zunni	Forest and Wood Sciences, Colorado State University

The recommendations complemented information already gathered by the ACOS staff from Sahelian farmers and herders. Sources of well-selected seed were identified and seed orders were then placed on the basis of the recommendations received (see Appendix B). All seed contributed by overseas suppliers was directed to BOSTID through H. R. Hanes of the United States Department of Agriculture's Plant Germplasm Quarantine Center.

Two categories of species trials--formal and informal--were conducted by ACOS under the current grant and are described in the following sections.

Formal Trials

Uniform, highly structured, species elimination trials were undertaken principally to better relate performance to selected site variables. Ten trial sites were identified that were representative of the range of environmental variation within the northern Sahel: Calheta, Cape Verde; Boutilimit, Nouakchott, and Selibaby, Mauritania; Bandia and Saint-Louis, Senegal; Bandiagara and Fatoma, Mali; and Guesselbodi and Tchin-Tabaraden, Niger. Because the trials were characteristically attached to existing projects, it was agreed that no more than 20 species could be tested without imposing an unacceptable management burden on cooperating researchers. After the comments and recommendations on species of potential importance to the region were reviewed, it was decided that the trials would include an affinity grouping composed entirely of leguminous trees: *Acacia albida*, *A. aneura*, *A. cambagei*, *A. ligulata*, *A. nilotica* subsp. *adstringens* (= *A. nilotica* var. *adansonii*), *A. nilotica* subsp. *tomentosa*, *A. senegal*, *A. tortilis* (= *A. raddiana*), *A. tumida*, *A. victoriae*, *Leucaena leucocephala* (K8), *L. leucocephala* (K500), *Parkinsonia aculeata*, *Prosopis* hybrid (PC 005), *P. africana*, *P. alba* (0166), *P. alba* (0388), *P. glandulosa* var. *glandulosa*, *P. juliflora*, and *P. velutina* (0457). A substitution series including *Leucaena leucocephala* (K30), *Prosopis* hybrid (PC 004), *P. alba* (JO 053), and *P. velutina* (PC 035) was also provided in the event of inadequate germination, nursery failures or outplanting accidents. The reasons for focusing on legumes include the following:

- Legumes, if associated with their specific rhizobia, are capable of increasing nitrogen availability in nitrogen-deficient Sahelian agro-silvo-pastoral systems. With the establishment of the West African Microbiological Resources Center (MIRCEN), rhizobial inoculum will be made available that will enable legumes to "fix" atmospheric nitrogen, thereby increasing both their productivity and nitrogen contributions to Sahelian agriculture and environmental systems.

- Legumes, such as *Acacia* and *Prosopis* spp., provide a range of products and applications that relate particularly well to the needs of the Sahel. For example, they provide food for human

consumption, fodder, fuel, building materials, conservation benefits, bee forage for honey production, marketable gums, and other products.

- The trees selected for the trials can be directly seeded, thus increasing their desirability for village forestry efforts without nursery components and avoiding complications often associated with inadequate nursery management.

- In addition to ease of management, the trees included in the trials are generally considered to be easily germinated, offer relatively rapid initial growth, are highly adaptable, are drought tolerant, coppice, seed profusely, are in most instances good biomass producers, and are appropriate for conservation plantings and site amelioration.

- Species trials require substantial investments of time and money. The demonstrated hardiness of the species selected, in the Sahel or under conditions analogous to those encountered in the northern Sahel, would reduce the risk of failure. While such failures can be valuable in scientific terms, they can be highly discouraging to researchers, officials, villagers, and others whose support is essential to the successful implementation of forestry projects.

The trials were designed in consultation with foresters representing AID, FAO, World Bank, IDRC, ISRA/CNRF, the Commonwealth Forestry Institute, and the USDA. The design used draws heavily from FAO and CFI experience and is compatible with the FAO/International Board for Plant Genetic Resources (IBPGR) provenance trials in arid and semiarid regions. The short-term objectives of the trials were as follows:

- To compare the performance of the various native and exotic accessions included in the trials.

- To identify candidate species for later provenance trials.

- To indirectly identify additional promising species through the analysis of vegetation associated with the trial accessions in their immediate area of origin. If, for example, trial accession *Prosopis alba* (0388) were to perform particularly well in trials at Guesselbodi, Niger, other species directly associated with the parent tree in Argentina, from which accession 0388 is derived, might be considered for collateral trials--in this case, *Celtis tala*, *Prosopis nigra*, *P. caldenia*, and other components of the local "espinal" plant community.

- To develop a model for species selection based on the relationships between plant performance and site variables demonstrated in the trials. It is hoped that this model will permit project developers to introduce critical site variables

into a computer program and receive a readout of promising species for their project needs.

- To provide training in species evaluation.

- The trial sites would serve as seed sources for accessions proved to be both useful and well adapted in the course of the trials.

- To provide limited but significant wildlife habitat and environmental amelioration simply through the potential establishment of 2,000 trees on each trial site. In our trial memorandum of April 12, 1983, it was suggested that the trials ". . . be situated in such a way that they can provide additional benefits. For example, established in watershed areas, located to the north-east of villages or degraded well points in order to serve as shelterbelts and/or future browse reserves as well as sources of seed for dispersal by animals, wind, and water."

Although a separate, more detailed report concerning the formal ACOS trials will be issued in the near future, sufficient data is now in hand to comment briefly on the implementation and prospects of the trials. The trials were undertaken by counterpart institutions on only 4 of the 10 proposed trial sites. Trials were not undertaken on the other sites for a variety of reasons: unexpected complications in protocol arrangements between the local researchers and national forest services was the principal reason given; the belief that the trials were being initiated too late in the year was an important consideration for some; the delayed arrival in the Sahel of the responsible researcher working with a technical assistance program affected one trial site.

Many of the problems and misunderstandings could have been avoided through better communication with workers in the field, which was difficult to coordinate from Washington. In the original proposal for the current ACOS program, it was proposed "that [a] part-time consultant be assigned to the Sahel Institute in Bamako, Mali, to coordinate Academy activities and contribute to the further development of the Institute's capabilities." Had funds been available for the support of such an individual (whose technical training was to have been in the area of forestry and ecology), the trials could have been better explained, implemented, and supervised. Judging from some letters and cables received from the Sahel, it is also apparent that the trial protocol, supporting memoranda, and other related documents were either unclear or unread. In some instances, it appeared that cooperating researchers had confused the nursery requirements for some of the more slowly developing species in the informal trials with those of the rapidly developing species in the formal trials. For example, a May 6, 1982, cable received from a colleague in Senegal indicated that ". . . it is very late to begin seed trials for this year." When the seed later arrived in Senegal it was passed on to ISRA/CNRF officials who planted it in July and August with satisfactory results (see Table 1). In the absence of an ACOS field representative to provide

TABLE 1 Species Trial Results After Six Months

Trial Accession*	Germination (%)	Planting Date	Results after 6 Months			
			Survival (%)	Height (cm)	SDEV (%)	Performance**
Acacia senegal (12791)	40	8/12/82	89	67.7	29	Excellent
A. cambagei (13435)	50	8/12/82	94	25.9	38	Excellent
A. ligulata (13425)	64	7/21/82	70	83.2	23	Excellent
A. victoriae (13271)	87	7/21/82	98	95.2	24	Excellent
Prosopis (PC 004)***	48	7/21/82	100	67.2	89	Excellent
Prosopis (PC 005)	51	7/21/82	100	67.2	89	Excellent
P. alba (0166)	95	7/21/82	99	90.5	44	Excellent
P. alba (0388)	73	7/21/82	98	92.2	78	Excellent
P. glandulosa var. *glandulosa* (PC 032)	86	7/21/82	100	110.4	28	Excellent
P. velutina (0457)	86	7/21/82	99	103.5	34	Excellent

Source: O. Hamel, Senegalese Forestry Research Center (ISRA/CNRF), March 1983

*Only 10 of the 20 accessions included in the formal ACOS-sponsored trials are being evaluated by the CNRF. The others are of species already included in CNRF trials at the Bandia Research Station.

**CNRF evaluation; criteria unknown.

***The field data for PC 004 and PC 005 were combined in the reporting forms received.

NB None of the CNRF plantings were inoculated, which is a factor to be taken into consideration in evaluating survival, height, and standard deviation. Site conditions: The average annual precipitation at Bandia is 400 mm. The 1982 rainy season was described as being normal. The topography of the station is generally flat. The natural vegetation is *Acacia*, *Adansonia*, and *Boscia* on deep, tropical ferruginous soils.

assistance and clarification, the trial protocol requested that specific questions regarding the trials be directed to the ACOS staff. No requests for advice or further information were received.

Three of the researchers who were unable to carry out the trials in 1982 are undertaking them at the present time. ISRA/CNRF is now directly involved in the trials in Senegal, and the possibility of inclusion in the 1983 trials has been discussed with the Malian Forest Service. The 1983 trials will be based largely on the protocol document provided for the 1982 trials . The changes are relatively minor: a fifth replication has been added for destructive sampling; only two of the replications are to be inoculated; the application of superabsorbent technology to seedling establishment will be tested; the inoculum provided by the University of Hawaii, the soil-testing paraphernalia provided by the USDA, the seed, and the trial protocol will be sent in a single shipment (see Appendix C). Arrangements are currently being made for the coordination of the 1983 trials and the evaluation of the data generated.

Informal Trials

The principal vehicle for increasing biological diversity under the current ACOS grant has been the informal species trials. As of mid-May 1983, ACOS has provided approximately 891 seedlots of some 183 accessions to 86 sites. Of the recipients, approximately 32 percent were AID employees; 28 percent were individuals associated with research institutions; 15 percent were representatives of national forestry and agricultural services; 11 percent were representatives of voluntary organizations such as the Peace Corps, British Volunteers, and the Lutheran World Federation; 8 percent were private individuals; and 6 percent were connected with French, German, and Swiss technical assistance agencies. These figures include some shipments of seed to destinations other than the Sahel in connection with research arrangements (for example, the Desert Botanical Garden in Phoenix, Arizona), exchange agreements (for example, CSIRO/Australia), demonstrated need (for example, Mennonite Central Committee efforts in Lebanon), and requests from non-Sahelian AID missions (for example, AID/Burundi and AID/Jordan). A list of seed shipments is attached to this statement as Appendix D. An alphabetical listing of species forwarded to the Sahel by the ACOS is included as Appendix E. A current listing of seed available is attached as Appendix F.

Although most ACOS accessions have multiple uses, they can generally be divided into four categories: (1) new, drought-tolerant food crops such as grain amaranth, tepary beans, and 60-day maize, (2) forage crops such as saltbush, siratro, and stylosanthes, (3) economic crops such as jojoba and *Acacia senegal*, which produces gum arabic, and (4) a wide variety of trees and shrubs.

The "new" food crops have been made available because of their potential to assure food sufficiency in marginal areas with little or highly irregular rainfall. Thus far, the major donors active in the Sahel have tended to disregard this aspect of the program, or regard it as a novelty. The principal support has come from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) station at Sotuba, Mali, and the International Livestock Centre for Africa (ILCA) station at Niono, Mali. This aspect of the program is of critical importance to the stabilization of rainfed agricultural production and should be pursued on an expanded and more systematic basis. It might be added that one-half of all ACOS seed for food crops was forwarded to the Sahel Institute in Bamako, Mali, for redistribution to researchers within the Sahel region. The distribution statistics contained in this statement do not reflect redistribution by the Institute or other seed recipients.

Perhaps the most systematic and immediately rewarding trials to date have involved forage crops. Trials focusing on the performance of Atriplex, Centrosema, Desmanthus, Leucaena, Macroptilium, Phaseolus, Stylosanthes, Tarchonanthus, and Tylosema species have been undertaken by the ISRA/National Laboratory for Livestock and Veterinary Research (LNERV) in Senegal and in association with ILCA efforts in Mali. Essentially the same accessions have been given to Maryam Niamir for trials associated with AID's Bakel Livestock Project in Senegal and to Robert Bement for trials associated with AID's Integrated Livestock Production Project in Niger. The ISRA/LNERV trials have proved the accessions involved to be well adapted to the Sangalkam area and are currently in their second generation on less sheltered sites. The AID trials are to be initiated this year.

Relatively little emphasis has been placed on economic crops. ACOS has, however, promoted the use of economically attractive species such as Acacia senegal in environmental rehabilitation projects and has explored the area of biomass substitutes for liquid fuel (for example, the use of degummed vegetable oils as diesel fuel and promising new energy crops that might be grown on marginal lands).

Every effort is made to provide basic information regarding each species forwarded to the field. This information often takes the form of BOSTID reports (such as Tropical Legumes, Leucaena, and Firewood Crops), governmental farmers' bulletins, appropriate articles, reprinted sections of technical monographs, or research reports. Identifying or generating appropriate materials has been an ongoing effort and one that requires still greater attention. Rhizobial inoculum is provided as available for leguminous accessions. This service is to be better integrated into the program through agreements with the NifTAL Project at the University of Hawaii and the West African MIRCEN. In the past, inoculum had been provided by the Nitragin Company, Milwaukee, Wisconsin. The performance of the accessions provided by ACOS is recorded on basic reporting forms written in French and English (see Appendix G).

The ACOS also responds to requests for further information concerning the characteristics or potential of various species. For example, the Prefect of Barkéol, Mauritania, observed that plant

species such as Cissus quadrangularis and Adenium obesum have traditional applications in pest control, and requested further information regarding their chemical properties and commercial potential. This information was obtained from economic botanists at the Smithsonian Institution and was forwarded, through the Lutheran World Federation, to Mauritania. The ACOS also assists AID missions and other institutions in their efforts to obtain large quantities of seed for range improvement, agricultural, or forestry projects. For example, sources of Stylosanthus guyanensis, S. hamata, S. humulis, Cenchrus ciliaris, Leucaena leucocephala, and Calliandra calothyrus were identified in response to a cable from Scotty Deffendol of AID/The Gambia's Mixed Farming and Resource Management Project. The ACOS staff has further assisted with the identification of research contacts and appropriate individuals to staff AID projects. ACOS staff members have also been involved in studies, conferences, and other activities in an effort to deal more effectively with conservation and development issues in the Sahel and to alert others to the problems and opportunities of the region.

Collateral Research

In addition to the trials themselves, ACOS has initiated or supported collateral research that will add to current knowledge of the species involved. For example, Brent Tisserat of the USDA's Fruit and Vegetable Chemistry Laboratory in Pasadena, California, has been given seed to determine the susceptibility of various native Sahelian species to propagation by tissue culture; James Duke of the USDA's Economic Botany Laboratory at Beltsville, Maryland, was given seed to conduct research in seedling characterization; Harold Keyser of the USDA's Nitrogen Fixation Laboratory at Beltsville has agreed to study population levels of native rhizobia in the trial sites and the effectiveness of the strains present in nitrogen fixation; Jake Halliday of the University of Hawaii has been given seed to identify the most effective strains, both native and exotic, for legume inoculation; G. E. Wickens of the Royal Botanic Gardens at Kew was provided with 14 ACOS accessions to be grown out as exhibits in the upcoming Kew International Conference on Economic Plants for Arid Lands.

Recommended Future Activities

- An historical survey of forestry research, natural forest management, and reafforestation projects in Africa south of the Sahara--to provide vital information on species introductions and performance, to review research methodologies, and to evaluate project successes or failures before, during, and subsequent to the colonial period. A thorough review of literatures and activities relevant to the forestry sector would be used to develop project-identification guidelines for future forestry and environmental programs.

- Continuing efforts in species evaluation and documentation and the conservation, multiplication, and distribution of germ plasm:

  -- ACOS believes that well-supervised species trials, drawing on the experience gained in this study should be undertaken on an expanded basis. Where possible, these trials should be undertaken at forestry schools or established forestry research centers.

  -- ACOS feels it should continue and expand its role as an interim source of seed until adequate facilities and mechanisms can be established in Africa.

  -- A particularly important proposed effort would be the establishment of a regional germ plasm bank for West Africa. The bank would be responsible for the conservation and documentation of seed, as well as for storing and supplying seed in quantities sufficient for use in major forestry and environmental rehabilitation projects. The bank could be incorporated into the exisiting infrastructure of the West African MIRCEN in Senegal. Hence, seed supplied by the bank could be accompanied by inoculum produced by the MIRCEN (such as Rhizobium, mycorrhizal fungi, and Frankia), if appropriate.

  -- It is further recommended that a Sudano-Sahelian Botanical Research Center be established for the conservation and study of native and exotic dryland flora. Research in appropriate silvicultural techniques would be undertaken. Discussions concerning this project have been held with Sahelian officials, AID foresters, and officials of the Royal Botanic Gardens at Kew. The rapid rate of decline in biological diversity and rise in species extinctions lend special urgency to the creation of this research center. The application of innovative techniques, such as the use of tissue culture to rapidly multiply endangered plant species and accelerate programs of selection should be incorporated into the center's program of research. It has been suggested that the center be established near either Bamako, Mali, or Niamey, Niger.

3. Publication: Agroforestry in the West African Sahel

Contractual Statement of Responsibility

"A report will be published listing promising trees, shrubs, and drought tolerant crops among which are those identified as a result of trial plantings initiated under the last Academy contract (AID/afr-C-1354) for activities in the Sahel, for distribution to organizations and governments involved in agricultural and forestry development activities in the Sahel."

Background

"Agroforestry" or, more properly, agro-silvo-pastoralism, is simply a new term for the old practice of growing woody plants with agricultural crops and/or livestock on the same land. Contrary to most areas of Africa, agroforestry has long been practiced in the Sahel in areas where staple crops such as millet, sorghum, and cowpeas are grown.

These agricultural crops are frequently grown where different trees (depending on site conditions such as rainfall, soils, slope, etc.) are maintained and often protected by the local people. The value of species such as Acacia albida (apple-ring acacia), Adansonia digitata (baobob), Borassus aethiopum (ronier), Tamarindus indica (tamarind), Parkia clappertoniana (West African locust), Butyrospermum paradoxum subsp. parkii (shea-butter tree), and many others is well known and appreciated by farmers and herders alike. Historical evidence underscores the importance of these trees to residents of the Sahel long before rural development--let alone agroforestry--became a focal point of international donor efforts.

Although studies on the symbiotic relationships existing among trees and crops and animals have been undertaken over the last several decades (for example, research at the Agricultural Research Center at Bambey, Senegal, on the benefits of Acacia albida was carried out as far back as the late 1930s), the many reasons why and how these trees benefit traditional resource use patterns has never been fully understood by Western agriculturalists.

Nevertheless, certain generalizations can be made. Vegetative cover and biological diversity are not only essential to the maintenance of stable environmental systems; they are also important to the maintenance of stable agricultural systems. While monocultural agriculture systems can be extremely productive, they require complex management, heavy inputs to replace the continual drain of nutrients, and careful attention to outbreaks of disease or predation which can destroy an entire crop. Mixtures of species can produce a variety of products; the complex root structure assists in retrieving nutrients from deep in the soil, holds moisture and reduces erosion, and is much more resistant to disease and moisture stress than are simpler systems (see Figure 2).

ACOS has long supported the further development of agro-silvo-pastoral systems in the Sahel. These systems appear to represent a particularly reasonable and attainable solution to the needs of the region for more stable and sustainable systems of food supply, the rehabilitation of degraded croplands, and the most effective use of the marginal lands increasingly devoted to agricultural use. These systems have the further advantage of being familiar to traditionalist Sahelian farmers, so that they can emerge as extensions of existing practices with the necessary management capabilities already established in rural populations. Agro-silvo-pastoral systems can also serve to increase wildlife habitat, thereby restoring the role of wildlife in seed dispersal and providing rural populations with bush meat.

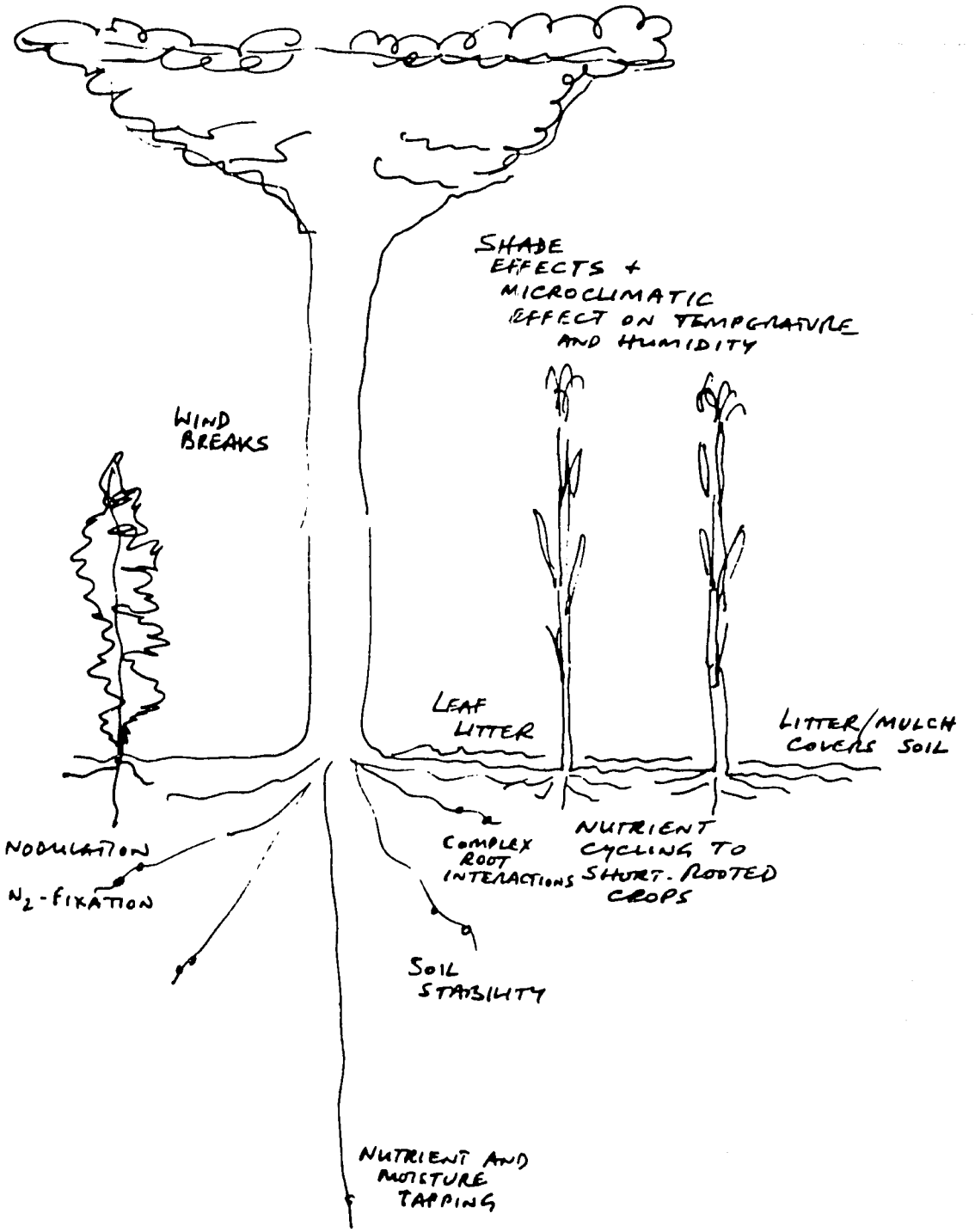

FIGURE 2 Interactions within agroforestry systems.

Activity Summary

This study was undertaken to provide development planners with further information regarding the history, nature, and potential of agroforestry in the Sahel. The study explores traditional systems of agroforestry, the relevance of agroforestry to the modern Sahel, the uses and potential of agroforestry, and presents a methodological statement on the diagnosis and design of agroforestry systems in the Sahel region. The study also contains criteria for species selection and a list of 114 tree species, indicating the range of uses of each. Seed for many of these species is currently being distributed by ACOS to "organizations and governments involved in agricultural and forestry development activities in the Sahel" (see Appendixes D, E, and F). The report also includes a case study drawn from the Ferlo region of Senegal.

Principal Contributors

The principal contributors to this report were Leonard Berry of Clark University; Francis LeBeau, former supervisory agricultural chief for AID programs in Africa; Hans-Jürgen von Maydell of the Institute for World Forestry in West Germany; John Raintree of the International Council for Research in Agroforestry (ICRAF); natural resources management consultant James Thomson; and Fred Weber of International Resources Development and Conservation Services. Other individuals who made significant contributions to the report include Robert Fishwick of the World Bank; Peter Freeman and George Taylor II, of AID; and Marilyn Hoskins of the Virginia Polytechnic Institute.

Recommended Future Activities

- Produce a report on underexploited opportunities for development related to the economic potential of native and exotic plant and animal species that thrive, or could thrive, under Sahelian conditions. The report would:

  -- Evaluate marketable gums produced by neglected indigenous species such as Acacia seyal, and by well-adapted exotics such as Prosopis juliflora.

  -- Identify plants capable of contributing to the control of disease. For example, the fruit of Balanites aegyptiaca, when made into an emulsion, is said to be lethal to the snails that are the intermediary host of schistosomiasis and to the water flea that carries the guinea worm disease. Also, some naturalized plants such as Aloe barbadensis are used in pharmaceutical and cosmetic products.

-- Identify drought-resistant subsidiary food plants such as Cordeauxia edulis (ye-eb) and Tylosema esculentum (morama beans).

-- Explore biomass substitutes for liquid fuel, such as the use of degummed peanut oil as diesel fuel.

-- Examine the exploitation of protein-rich algae such as Spirulina platensis (which is native to Lake Chad and is eaten by the people of the region) as inexpensive sources of food, livestock feed, fuel, and fertilizer.

-- Reexamine the potential contributions of camels, goats, water buffalo, and other underexploited species to regional livestock programs.

-- Consider new, easily grown commercial crops, such as Volvariella volvacea (paddy-straw mushrooms), which have now been adapted to small-scale cultivation in rural areas of the tropics.

-- Evaluate the potential contributions of wildlife species to Sahelian economies.

The purpose of the report would be to identify a broader range of economic activities, to attach greater importance to the conservation and utilization of existing resources, stimulate interest, and help focus research. The format of this report would be based on that of the BOSTID report, Underexploited Tropical Plants with Promising Economic Value (1975).

4. Scientific Networking to Reinforce Development Activities and Strengthen Regional Institutions such as the Sahel Institute

Contractual Statement of Responsibility

> "The Sahel Institute staff will be involved in regional activities in the ecology-forestry sector and will be assisted in the gathering, storage, and dissemination of scientific and technical information, thus helping them to realize their original raison d'etre as the prime research coordinator in the Sahel area."

Background

The NRC was instrumental in the establishment of the Sahel Institute (see Appendix A), and has long sought to be of assistance in its further development. With the support of AID, discussions have been held with Institute officials in Bamako and in Washington concerning the form this assistance might take. ACOS participated in the first

meeting of the Institute's Scientific and Technical Council in 1979 and was asked to assist with the preparation of the Institute's quinquennial program (1981-1985) of activities in the ecology/environment sector. This meeting was held in 1980 in Bamako, with the further participation of the United Nations Sudano-Sahelian Office (UNSO) and the CILSS Ecology and Forestry Team. Despite these discussions and activities, it has been difficult to establish a constructive, continuing relationship with the Institute.

Activity Summary

Under the current grant, the ACOS staff has met with Sahel Institute, International Development Research Centre (IDRC), and AID officials in Washington, Ottawa, and Bamako concerning the Institute's efforts to strengthen its Sahelian Scientific and Technical Information and Documentation Network (RESADOC). These meetings initially focused on the proposed use of a Hewlett Packard 3000 computer and the MINISIS system to bolster RESADOC capabilities.

To further support the RESADOC program, ACOS has regularly provided the Institute with documents relevant to development issues in the Sahel.

ACOS contributions to the Sahel Institute's environmental program were complicated by the absence of an Institute staff officer with explicit responsibility in this area during much of the current grant period. This situation changed with the addition of forester Modibo Sidibé to the staff, but his appointment occurred too late to initiate new activities under the existing grant. Nevertheless, ACOS has provided seed for forestry and agricultural research, and it has consistently encouraged an Institute role in coordinating and monitoring species trials in the Sahel. (As noted above, one-half of all ACOS germ plasm for "new crops" was directed to the Institute for redistribution to researchers in the Sahel.)

Other ACOS activities in the area of institution building and scientific networking--in addition to those described in connection with the Sahel Institute, the development of the regional Microbiological Resources Center (MIRCEN), the species trials, and other items contained in this statement--include frequent ACOS briefings for AID, World Bank, and officials or technicians assigned to the Sahel, contributions to international meetings concerned with the Sahel region, and efforts to stay abreast of the activities of various donors and better assure the effectiveness and complementarity of regional scientific networks. For example, ACOS works closely with the AID-sponsored Environmental Training and Management in Africa (ETMA) program, the African Bioscience Network sponsored by the International Council of Scientific Unions and UNESCO, the emerging MIRCEN network, and the International Union for Conservation of Nature and Natural Resources (IUCN). In some instances, the contacts have permitted the ACOS to propose useful activities to be undertaken by others. For example, the ACOS has recommended that the IUCN consider the creation

of a reserve for desert wildlife in Mauritania, undertake a pilot urban-fringe rehabilitation project in and around Nouakchott, Mauritania, and cooperate with the Sahel Institute in reconciling national and regional environmental programs with the IUCN's World Conservation Strategy. The recommendations have been accepted and acted on by the appropriate IUCN commissions.

A representative listing of ACOS networking contacts is attached to this report as Appendix H.

Recommended Future Activities

- It is proposed that ACOS continue to promote the exchange and exploration of ideas and information related to environmental rehabilitation and agricultural production in the following ways:

  -- By arranging and coordinating visits by non-Sahelian scientists to the Sahel to stimulate and focus scientific research, and visits by Sahelian scientists to dryland research centers and reclamation projects in the United States for study and observation.

  -- By providing Sahelian research institutions, including the Sahel Institute, with advice, information, and contacts through correspondence, scientific exchange visits, and workshops on specific topics, such as problems of Rhizobium survival in degraded sites and natural forest management.

  -- By further developing and providing access to a network of scientific and technical specialists who will respond to requests for advice and assistance from AID officials and technicians.

5. Establishment of a West African Microbiological Resources Center

Contractual Statement of Responsibility

> "A meeting will be held to establish a regional microbial resource center in Senegal. This center will produce inoculum to be made available to institutions involved in assisting Sahelian countries concerned with agricultural and environmental development projects involved with leguminous trees, shrubs, and food crops."

Background

It is generally recognized that lack of nitrogen is more limiting to the growth of trees, shrubs, grasses, and crops in the Sahel than lack of any other plant nutrient. In recent years this problem has been further aggravated by accelerating environmental degradation which has

both eliminated or numerically reduced many leguminous species capable of biological nitrogen fixation and eliminated the ground cover necessary to regulate soil temperatures and soil-water relationships necessary for the survival of nitrogen-fixing bacteria (principally Rhizobium spp.). This problem is critical since nitrogen is an essential component of all life forms, being a key constituent in the chemical structure of proteins.

The need to establish a source of rhizobial inoculum for development projects in West Africa emerged from working discussions with the Mauritanian government, AID, and ACOS in 1979. Soil samples taken by ACOS in areas formerly dominated by leguminous species, such as Acacia senegal in Mauritania, and analyzed in the USDA Nitrogen Fixation Laboratory at Beltsville, Maryland, were devoid of rhizobia and other critical soil microorganisms. Further discussions were held with ISRA and the Secretariat d'Etat a la Recherche Scientifique et Technique (SERST) officials in Senegal, as well as with researchers at the USDA and with AID and IDRC officials.

In March 1981, ACOS organized additional discussions concerning the development of a regional microbiological culture collection in West Africa. These discussions included representatives of UNESCO, ORSTOM, Nitragin Company, ICRISAT, the University of Minnesota, the Pasteur Institute, and the Microbiological Resources Centers (MIRCENs) located in the United States at Pala, Hawaii, and Beltsville, Maryland, and in Nairobi, Kenya, and Porto Alegre, Brazil. It was concluded that the West African culture collection should be established within the framework of the United Nations Environment Programme, UNESCO, and the International Cell Research Organization MIRCEN program. Furthermore, it was suggested that the proposed MIRCEN be located in Senegal because of the country's pioneering efforts in microbial technology. Finally, following discussions and recommendations by Senegalese officials and scientists, it was proposed that the MIRCEN be established at an existing research center or university department to facilitate donor assistance as well as support from UNESCO's major regional project in applied microbial technology for Africa and the Arab states. Further discussions were held in Senegal from August 31 to September 5, 1981.

The Nature of Biological Nitrogen Fixation (BNF)

The problem of nitrogen deficiency is most effectively addressed through the introduction or reintroduction of legumes into agricultural and environmental systems. Leguminous plants are especially attractive when sustained productivity is sought from low-input systems, because of their ability to be both self-sufficient in nitrogen and to indirectly contribute nitrogen to their nonleguminous companions. In general, biological nitrogen fixation by symbiotic associations of plants with microorganisms is economically more sound and environmentally more acceptable than the use of nitrogen fertilizer in agriculture.

In order to fix nitrogen, legumes must be inoculated. This is done by introducing legume bacteria into the soil to enable plants to fix, or change into a usable form, atmospheric nitrogen. Atmospheric nitrogen is abundant. About 80 percent by volume of the air we breathe is pure nitrogen in a free, or uncombined, state. Every hectare of land surface has about 86,450 tons of this free nitrogen above it.

Free nitrogen, as such, is useless to plant or animal life. To become useful, it must combine with other elements. This process of combination can be accomplished industrially, but at a very high energy cost. Nitrogen can also be forced into combination with other elements by powerful influences such as lightning or by bacteria growing on the roots of leguminous plants.

When inoculated legumes begin to grow, the legume bacteria invade the root hairs. The legumes form growths on the roots called nodules. The bacteria live in these nodules, establishing a mutually beneficial relationship with the host plant. The plant furnishes the necessary sugar, or energy. The bacteria use this energy to change the free nitrogen of the atmosphere into a form that the plant can assimilate and use to build protein. The nitrogen is then said to be "fixed." Although the quantities of nitrogen fixed by the bacteria differ, depending on the kind of legume, the effectiveness of the bacteria, soil conditions, and the presence of necessary plant-food elements exclusive of nitrogen, it is generally on the order of 100 kg/ha/year in the tropics--the equivalent of applying 440 kg of urea (assuming a 50 percent crop uptake). In the United States, this would translate into a possible value of $270/ha/year for the free nitrogen a legume can fix. Levels as high as 800 kg/ha/year are within the potential of some tropical species. In Senegal, the leguminous Acacia albida, established as a field tree in association with crops such as millet and groundnuts, has increased yields on infertile soils from approximately 500 kg/ha to 900 kg/ha (with a tree density of 45 per hectare).

Activity Summary

Under the current grant, further meetings and discussions concerning the development of a West African microbiological resources center (MIRCEN) were held in Senegal in November 1981, March 1982, and November 1982. Additional meetings were held in Ottawa and Quebec, Canada; Paris, France; and in Washington. These meetings and discussions involved officials and scientists representing SERST, ISRA (and the CNRA, CNRF, and LNERV divisions of ISRA), UNESCO, AID, FAO, the IDRC, Laval University, the USDA, Tropical Agronomic Research Institute (IRAT), the World Bank, ORSTOM, the Pakistani National Agricultural Research Centre, the East African MIRCEN, the Porto Alegre MIRCEN, the University of Hawaii's NifTAL Project, Nitragin Company, Agriculture Canada, the Karolinska Institute, the International Foundation for Science (IFS), the Foundation for Microbiology, the Asociacion Latino-Americana de Rhizobiologos, the University of Florida, Oregon State University, and the University of Minnesota.

As a result of these meetings and discussions, ACOS prepared a draft document for the establishment of a West African MIRCEN. The Senegalese government identified the National Center for Agricultural Research at Bambey (ISRA/CNRA) and the National Center for Forestry Research (ISRA/CNRF) in Dakar as the sites for the MIRCEN. The government also appointed Sitapha Diatta of ISRA as interim director of the MIRCEN program. The program is currently directed on a full-time basis by Mamadou Gueye.

ACOS has also arranged for the services of a senior consultant to assist with the early development of the MIRCEN. The consultancy is financially supported by a grant from the New York-based Foundation for Microbiology amd will be undertaken by microbiologist Lucien Bordeleau of Agriculture Canada. (An earlier proposed candidate for the consultancy, Carlos Batthyany of Uruguay, suffered a serious stroke and found it necessary to withdraw.) Dr. Bordeleau's consultancy will take the form of multiple visits made at approximate intervals of 6 months over an extended period of time. The first visit is scheduled for May 15-June 10, 1983.

An important role of the West African MIRCEN will be the selection of effective rhizobial strains for the crops and agroclimatic conditions of the Sahel region. In addition to the selection, multiplication, and distribution of effective rhizobial strains, the MIRCEN will support long- and short-term training programs; will maintain a regional microbial culture collection; will produce and distribute a collection catalogue and publish a newsletter; and will identify and develop local and regional collaborative projects. For the Senegalese government, this MIRCEN is also seen as an initial step in developing a comprehensive, national biotechnology program.

APPENDIXES

APPENDIX A

ARID LANDS OF SUB-SAHARAN AFRICA
Staff Final Report
July 1974-December 1974

May 1, 1975

Dr. George S. Hammond
Foreign Secretary
National Academy of Sciences

Re: Report of NAS Advisory Panel on Arid Lands of sub-Saharan Africa

Dear George:

The following is the report of the Board's Panel on Arid Lands of sub-Saharan Africa which deals with problems of the long-term development of the Sahel. This letter summarizes and reports the principal conclusions and recommendations arrived at by the panel. The staff summary reports of the panel's meetings and appendices comprising working papers and minutes of these meetings have been compiled for transmission to AID as required by our contract with the Africa Bureau.

The NAS at the request of AID appointed BOSTID's Advisory Panel on Arid Lands of sub-Saharan Africa late in 1973 to "advise AID with respect to the critical medium- and long-term natural resource management problems of the drought-stricken region of West Africa, and to provide assistance in the design and implementation of U.S. participation in an international collaborative scientific effort being organized to address the emergency situation."

Over the past 12 months the panel (the list of members is appended) met formally five times and held special meetings to consider particular topics, such as the future climate of the Sahel region. In late October 1974 a group of panelists met with other international scientists and planners familiar with the Sahel at the Rockefeller Foundation Study and Conference Center at Bellagio, Italy to discuss strategies for the long-term development of the Sahel region. Individually, panel members met with a wide group of people knowledgeable about the Sahel, and visited the area during the period covered by the panel's report.

Rehabilitation and long-term development of the Sahel is a very large, complex and intractable set of social, economic and political, as well as technical, problems which the panel would be presumptuous to expect to treat in depth using the approach of intermittant short meetings. In addition the pace of events in the Sahel, where a large number of bilateral and international organizations are moving ahead rapidly with relief and rehabilitation operations, outstrips the capacity

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of even a full-time operational agency such as AID to monitor successfully. The value of the panel lay in the overview it provided to AID in reviewing some of its proposals, in responding to questions raised within AID, and in helping AID conceptualize strategies that will assist the Sahel countries in ultimately achieving economic self-sufficiency.

The highlights and conclusions of the panel's work are:

1. A discussion of AID's mid-term (1974-75) program of activities for the Sahel countries which enabled AID officials to reassess the problems associated with some of the large proposals such as tsetse fly clearance and provision of large areas of grazing reserve. AID has now reallocated its resources with respect to these problems in line with the panel's suggestions.

2. A critique of the draft report of the group at MIT with which AID contracted to produce alternative strategies for the long-term development of the Sahel. Since the decision to undertake the MIT study antedated the establishment of the NAS panel, and since the conclusions and recommendations of the final report by MIT were not available to the NAS panel before it completed its work, a critical review was not possible. Panelists concerns about the methodology of the study, however, were conveyed to AID and MIT representatives and perhaps contributed to a revised approach to the study. The final MIT report is being distributed to panelists for individual comment.

3. A special meeting on the future climate of the Sahel convened by the panel, chaired by Dr. Thomas Malone, which brought together a large group broadly representative of U.S. climatology. Opinion was divided as to the atmospheric conditions which cause severe drought, and as to man's ability to predict when they would occur, and whether or not future droughts will be more frequent and severe than those of the past. More information is necessary to improve our ability to predict drought, and attention is being given to this problem. Drought is unfortunately an inescapable feature of the Sahel region and planning must take into account and cope with the severe droughts which may be expected to occur periodically.

4. An international meeting held in collaboration with the Rockefeller Foundation at the Foundation's Study and Conference Center at Bellagio comprising a group of NAS panelists, scientists and administrators from Africa, Europe and international agencies in order to discuss strategies for the long-term development of the Sahel region. This meeting provided a unique opportunity for participants to exchange viewpoints and perceptions of drought-related problems. The panel's report of the Bellagio meeting and a Bellagio Working Paper prepared by the Rockefeller Foundation will be circulated widely to disseminate the conclusions and recommendations on opportunities for long-term Sahelian

development. We hope these will be used as a basis for programs of bilateral and international donor agencies. The conclusions and recommendations emphasized: a) the need for a systems approach to the utilization of available resources, and b) the need for an institutional mechanism in the region (a "Sahel institute") which would provide systems research and development to support the long-term development effort. Within these contexts efforts should be undertaken to:

. upgrade the nomadic-pastoral livestock system;
. improve the predictive capacity of meteorological services;
. improve the supply of information on soil and water resource development to farmers on a farm scale;
. accelerate food production, both crop and livestock, as the basis for food security for the region which will permit and support long-range economic diversification including such things as small scale agro-industry;
. improve understanding of the economics of marketing at the farm-level, within and between countries;
. improve infrastructure, roads and communications, in the area;
. ensure that in developing large-scale water resource projects in the great river basins of the area, opportunities for small-scale water resource development (such as described in BOSTID's More Water for Arid Lands) are not neglected; and
. above all, improve the level of education of the peoples of the region, adults as well as children, by all means (formal and otherwise) as the main basis on which long-term change can be effected in the area and on which all other development activities will depend.

At the panel's final meeting in December, members felt that the original mandate of the panel had been accomplished and it was agreed that therefore the panel as presently constituted should be dissolved. However, it was also agreed that a number of important tasks should be undertaken which might require a different panel or other mechanisms.

Accordingly the panel recommends to BOSTID that the following tasks be undertaken in consultation with AID and other agencies and organizations:

1. Collecting, collating, and analyzing the recent drought experience. A great deal of information has been derived from the recent drought, which should be systematically collected before it is irretrievable and analyzed for the lessons which should be preserved to reduce the impact of the next drought.

2. Providing a focus for U.S. scientific and technological inputs for problems of long-term self-sufficiency in arid lands around the world, particularly in Africa.

3. Implementing the ideas outlined in the Bellagio report, summarized above. To do this AID should consider establishing working groups to address the specific problem areas, e.g., upgrading the nomadic-pastoral livestock system. These working groups should not undertake studies of the problems per se but rather design projects and programs for donor agency financing and implementation to remove the critical constrajnts towards progress in development. Each working group should of course include African participants from the Sahel countries; certain of them, e.g., to consider a systems approach to development planning, small-scale water resources, etc., may be suitable topics for NAS participation following the recent BOSTID studies of these topics.

On behalf of the panel, I would like to convey to you how much my colleagues and I have appreciated working together in this important and challenging area. We greatly appreciated the service and expertise of your staff in the conceptualization and implementation of the program. If individually or collectively we can be of service to BOSTID and the NAS in the future, please feel free to call on us to do so.

With warm wishes,

Sincerely,

John J. McKelvey, Jr.

APPENDIX B

PRINCIPAL SOURCES OF SEED FOR ACOS SPECIES TRIALS

1. Agricola du Tchad, N'Djamena, Chad
2. Arizona, University of
3. Asia Foundation, San Francisco, California
4. Baobab Farm Ltd., Mombasa, Kenya
5. Boyce Thompson Southwestern Arboretum, Superior, Arizona
6. California, University of, at Riverside
7. Cape Town, University of, Bolus Herbarium
8. Corporacion Nacional Forestal, Chile
9. Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia, Division of Forest Research
10. CSIRO, Australia, Division of Tropical Crops and Pastures
11. Desert Botanical Garden, Phoenix, Arizona
12. Florida, University of
13. Charles Geshekter, Chico, California
14. Charles Gritzner, Mesa, Arizona
15. Hawaii, University of
16. International Council for Research in Agroforestry (ICRAF), Nairobi, Kenya
17. Senegalese Institute of Agricultural Research, National Forestry Research Center (ISRA/CNRF)
18. Meals for Millions, Tucson, Arizona
19. Morocco, Forest Service
20. Native Seeds/SEARCH, Tucson, Arizona
21. Rodale Research Center, Emmaus, Pennsylvania
22. Sociedad Agricola Corfo (SACOR), Santiago, Chile
23. Southwestern Texas University
24. Texas A&I University
25. Texas A&M University
26. Texas Department of Health
27. Texas Tech University
28. U. S. Department of Agriculture
29. Utah State University
30. Western Australia Department of Agriculture

APPENDIX C

BOARD ON SCIENCE AND TECHNOLOGY
FOR INTERNATIONAL DEVELOPMENT

CABLE ADDRESS: NARBCO
TWX # 7108-22-9584
OFFICE LOCATION:
JOSEPH HENRY BUILDING
21ST STREET AND
PENNSYLVANIA AVENUE, N.W.

May 10, 1983

MEMORANDUM

TO: Participants in the National Research Council-Sponsored Species Elimination Trials

FROM: Jeffrey Gritzner and Carol Corillon, National Research Council (NRC)

SUBJECT: Trial Design, Implementation, and Assessment

The design and objectives of the 1983 species elimination trials differ little from those described in the 1982 trial protocol and related memoranda. The essential differences are as follows:

- A fifth replication is recommended for destructive sampling.

- There has been some substitution of species based on initial performance in the 1982 trials, as well as questions of seed quality and availability.

- Only two of the trial replications are to be inoculated.

- Rhizobial inoculum is included with each trial shipment.

- Soil testing instructions and paraphernalia are included with each trial packet.

- The application of superabsorbent technology to seedling establishment is to be tested.

In order to ensure the greatest degree of uniformity among the trials, this memorandum provides basic guidelines regarding design, implementation, and assessment. The guidelines have been adapted from information provided by the Forestry Department of the Food and Agriculture Organization of the United Nations (FAO). This has been done in an effort to make our trials and resulting information as complementary as possible to those of the FAO/ International Board for Plant Genetic Resources (IBPGR) Project on

The Office of International Affairs of the National Research Council serves the international interests of the National Academy of Sciences the National Academy of Engineering, and the Institute of Medicine

Genetic Resources for Arid and Semi-Arid Zone Arboreal Species. Proper use of the guidelines will facilitate the interpretation of the data from the trial sites, thereby increasing our understanding of plant performance in relation to differing site variables.

Please feel free to contact us at the National Research Council should you have any questions regarding the implementation of the trials. Cable Address: NARECO; Telex: 710-822-9589; Telephone: (202) 334-2298.

Project Objectives

The objective of the trials under the current NRC grant is to broaden the range of resources which can be employed to increase the stability and productivity of Sahelian agro-silvo-pastoral systems. They have been undertaken in response to assessments made by NRC teams in the Sahel and expressions of interest by Sahelian governments, regional organizations, and international donor agencies.

The trials will assess the growth and survival of the species selected in relation to local conditions in the various ecological provinces in which the trial sites are located.

It is expected that the trials will be maintained for three years by cooperating organizations with options to extend them for a total period of five or six years. After the initial three-year period, cooperating organizations could adapt the trials to their individual project requirements. In addition, special attention should then be given to the measurement of the various qualities of the individual species—such as gum production, pod production, overall biomass production, coppicing, etc.

To permit uniform assessments over the initial three-year period of the trials, the NRC has discussed various possibilities for trial monitoring and data assessment with the Senegalese Center for Forestry Research (CNRF), the University of Oxford, USAID, and the World Bank. It is anticipated that a systematic program for monitoring and assessment will emerge from these discussions. Continuing efforts will be made to involve the Sahel Institute in trial evaluation.

Experimental Design

The basic design to be used for the trials is a randomized complete block (see Sketch No. 1). It was prepared by the Commonwealth Forestry Institute at the University of Oxford and is the most commonly used design in forestry experimentation. While a number of designs were considered, the randomized complete block was selected because it is robust, it lends itself easily to statistical analysis

and the size of the experimental unit required will not overburden the volunteer participants. Adherence to the design is important to assure valid statistical analysis.

Each of the 20 accessions selected for the trials has been assigned an identification number between 1 and 20 by the NRC. This number is clearly designated on the seed packets and exact placement in the field is illustrated in Sketch No. 1.

Nursery Stage

The trial accessions should be planted in the nursery on or around June 1st. While specific planting instructions as well as any necessary seed treatment will be included with each packet of seed, we would like to emphasize the importance of careful attention to identification. Using identification techniques mentioned later, or any others you prefer, please ensure that seedlings are properly identified and are not moved unless adequately labelled. However, if plant identification is lost or if there is some uncertainty as to identity, be sure this problem is recorded as it can be factored out in the subsequent evaluations.

While watering and mulching are important, careful supervision should be given to ensure that seedlings are not watered excessively. Fertilizers should be used in the nursery and insecticides should be used in the establishment phase if necessary to control termites and other destructive insects. The Rhizobial inoculum included in each trial packet should be applied as indicated in the accompanying instructions.

As 125 seedlings per species, (2,500 seedlings in all) will be needed in the field experiments, at least double that number, (250 seedlings per species or a total of 5,000) should be grown in the nursery. Seedlings selected for outplanting should be as robust and uniform as possible and should be planted with the utmost care so that failures are not the result of poor planting practices.

Field Stage

The field site should be divided into five replications of equal area. Although edge effects are reduced in more compact arrangements, the actual placement of one replication in relation to another is not really important. What is important, however, is that each replication is as uniform as possible and that environmental variation within replications is minimized. Edge effects, shading from neighboring trees, soil type, depth and fertility of soil, slope, and previous land use in the field should be taken into account. Each replication should be treated as uniformly as possible. For example, each plot within the same replication should be planted on the same day by the same planting team or planter, and it should be weeded on the same day. A border should be established around the experimental area and a locally grown check/control species should be grown for comparison.

The total area needed for the experiments is approximately 2.5 hectares. A standard spacing of three meters between each seedling should be used and each of the 20 accessions should be represented in all five replications by plots of 25 trees per species, making a total of 500 trees per replication.

As mentioned above, the placement of a plot of 25 seedlings of one species within a replication is illustrated in Sketch No. 1 by the identification number assigned by the NRC to the accessions. For example, if the identification number of an accession of Prosopis alba seed were number 1, then 25 seedlings of P. alba would be planted, in a rectangular plot of five trees by five trees, in the poisition marked 1 in the trial design shown in Sketch No. 1.

Supplemental watering should be provided in the field only in cases of extreme need.

Identification

Considerable care should be taken at both the nursery stage and in the field experiments to ensure that correct identification of the species is made and maintained. Each planting location should be marked with a colored stick, flag, plastic, wooden or metal dividers, or other clear identification. Each experiment should be mapped in the nursery as well as in the field. The general layout for each plot in the nursery should be the same as in the field (i.e. seedlings in the field should come from the corresponding nursery block bed). Within each plot, the trees should be numbered as follows:

5	6	15	16	25
4	7	14	17	24
3	8	13	18	23
2	9	12	19	22
1	10	11	20	21

Tree No. 1 should be in the southwest corner of the plot.

Replacement plantings

Dead plants should be replaced in the field as soon as possible and the number, location, and date of replacements in each plot should be recorded on Form No. 6. However, all replacements should be made while there are still at least three or four weeks of rainfall remaining.

Protection

The experiments should be protected against fire and grazing or browsing animals, preferably by enclosing them and/or posting guards.

Assessment

Although the NRC will arrange for an assessment team to visit the trial sites to collect, analyze, process, and computerize the data should funds permit, we would appreciate it if the trial participants also made assessments by observing, measuring, and recording data. Species Trial Site Description Forms (No. 1), Nursery Record Forms (No. 2), Germination Record Forms (No. 3), Nursery Assessment Forms (No. 4), Field Record Forms (No. 5), and Field Assessment Forms (No. 6) are enclosed. To ensure maximum accuracy, it would be best if one Field Record Form and one Field Assessment Form were used for each plot.

The Nursery Assessment Form (No. 4) should be filled in about one week prior to outplanting; probably about the third week in July. The Field Assessment Form (No. 6) should be filled in about a month after outplanting and then once a year after that.

For further information regarding trial design, implementation, and assessment, please refer to J. Burley and P. J. Wood, A Manual on Species and Provenance Research with Particular Reference to the Tropics (Oxford: Department of Forestry, Commonwealth Forestry Institute, University of Oxford, 1976).

ATTACHMENT I

TRIAL ACCESSIONS

Identification Number

1 Acacia adsurgens (13738), Mulga. This seed was collected by CSIRO's Division of Forest Research at Wilton Park, Northern Territory, Australia. The seed was provided on behalf of the Australian Development Assistance Bureau (ADAB). It requires boiling-water treatment for germination. (See Appendix II.)

2 Acacia albida (82/598), Apple-Ring Acacia. This seed was provided by the Senegalese National Forestry Research Center (CNRF). It was collected in the Nayobe region of Senegal. Boiling-water treatment is recommended for germination.

3 Acacia cambagei (13487), Gidgee. This accession was collected by CSIRO 98 km. west of Windorah, Queensland, Australia. It was provided on behalf of ADAB. N.B.: The seeds of A. cambagei germinate rapidly without pretreatment, and the use of boiling water to hasten germination can be harmful.

4 Acacia coriacea (13768), Wirewood. This seed was collected at Rabbit Flat, Northern Territory, Australia by CSIRO. It was provided on behalf of ADAB. It requires boiling-water treatment for germination.

5 Acacia estrophiolata (13799), Ironwood. This accession was collected at Floodout, Northern Territory, Australia by CSIRO and was provided on behalf of ADAB. It requires boiling-water treatment for germination.

6 Acacia latzii (13780). This acacia was collected along Wallera Range Road in the Northern Territory of Australia. The seed was provided by CSIRO on behalf of ADAB. It requires boiling-water treatment for germination.

7 Acacia monticola (13773), Cajaput Tree. This accession was collected at Wannabi Hill, Northern Territory, Australia by CSIRO. It was provided on behalf of ADAB. Boiling-water treatment is recommended for germination.

8 Acacia nilotica subsp. adstringens (81/443), Egyptian Thorn. This seed, provided by CNRF, was collected near Louga, Senegal. Boiling-water treatment is recommended for germination.

9 Acacia senegal (82/594), Gum Arabic. This seed was provided by CNRF and was collected in the Northern Ferlo region of Senegal. Boiling-water treatment is recommended for germination.

10 Acacia tenuissima (13800). This seed was collected near Rabbit Flat, Northern Territory, Australia by CSIRO. It was provided on behalf of ADAB. A. tenuissima requires boiling-water treatment for germination.

11 Acacia tortilis subsp. raddiana (82/599), Umbrella Thorn. This accession was provided by CNRF. It was collected in the Nayobe region of Senegal. Boiling-water treatment is recommended for germination.

12 Acacia validinervia (13797). This seed was collected by CSIRO at Tylers Pass, Northern Territory, Australia. It was provided on behalf of ADAB. Boiling-water treatment is recommended for germination.

13 Acacia victoriae (13271), Elegant Acacia. This accession was collected 79 km. north of Charleville, Queensland, Australia by CSIRO. It is provided on behalf of ADAB. Boiling-water treatment is recommended for germination.

14 Leucaena leucocephala (K67). This accession is from Santa Cruz Porillo, El Salvador. It was grown out and collected at the Waimanalo Research Station of the University of Hawaii. Mechanical scarification is recommended for germination. Boiling-water treatment can also be used, but will result in lower germination percentages.

15 Prosopis africana (82/672). This seed was provided by CNRF. It was collected in the Bayottes Classified Forest in the Casamance region of Senegal. The seed should be mechanically scarified prior to planting. (See Appendix II.)

16 Prosopis alba (PC 062), Algarrobo Blanco. This seed was collected in Hemet, California by researchers from the University of California at Riverside. The trees are relatively thornless. The seed should be mechanically scarified to assure satisfactory germination percentages.

17 Prosopis chilensis, Algarroba. This seed was provided by the U. S. Department of Agriculture Germplasm Resources Laboratory at Beltsville, Maryland. The seed should be mechanically scarified prior to planting.

18 Prosopis glandulosa var. glandulosa (PC 032), Honey Mesquite. This seed was provided by the University of California at Riverside. The parent tree was grown from seed collected near Santa Ana, Mexico. It produced 12.6 kg of pods at four years of age. The seed should be mechanically scarified to assure satisfactory germination.

19 Prosopis juliflora (79/194), Mesquite. This seed was provided by CNRF. It was collected near Saint-Louis, Senegal. The seed should be mechanically scarified prior to planting.

20 Prosopis velutina (PC 035), Velvet Mesquite. This seed was collected from a tree at the Agricultural Experiment Station of the University of California at Riverside. The parent tree was grown from seed collected in Arizona. The tree produced 12.2 kg of pods in 1981. The seed should be mechanically scarified prior to planting.

Substitution Series

A Acacia aneura (12791), Mulga. This seed was collected by CSIRO in New South Wales, Australia and was provided on behalf of ADAB. It requires boiling-water treatment for germination.

B Acacia cowleana (13774). This seed was collected by CSIRO at Vaughan Springs, Northern Territory, Australia. It is provided on behalf of ADAB. A. cowleana requires boiling-water treatment for germination.

C Acacia farnesiana (11147), Sweet Acacia. This accession was collected in New South Wales, Australia by CSIRO and was provided on behalf of ADAB. Boiling water treatment is recommended for germination.

D Acacia holosericea (13771). This seed was collected near Vaughan Springs, Northern Territory, Australia by CSIRO plant explorers. The seed was provided on behalf of ADAB. Boiling-water treatment is recommended to aid germination.

E Prosopis alba (0388), Algarrobo Blanco. This seed was collected at Texas A&I University. The tree from which it was collected produced 64 kg (dry weight) of 40-44 percent sugar pods which were successfully fermented to ethanol by the MIT fermentation unit. The seed should be mechanically scarified prior to planting.

F Prosopis velutina (0457), Velvet Mesquite. This seed was provided by Texas A&I University. One of the most promising pod producers. At four years of age, the tree produced 13 kg of pods containing approximately 14 percent protein and 28 percent sugar.

Further information regarding the ultimate origin of the trial accessions, or the characteristics and productivity of the mother trees collected, can be obtained from the National Research Council.

If additional seed is required for any of the listed accessions, please contact the NRC immediately.

ATTACHMENT II

SEED TREATMENT

Seed Extraction

The seeds of several trial accessions must be removed from their pods. To do this, cut the pod with sharp shears over, but not centered on, a seed. If done properly, a small slit in the innermost capsule of the pod will be seen. Insert the sharp blade of the shear into the slit and squeeze the seed out.

This procedure may take a little while to master but can yield several hundred seeds per hour per worker. Low sugar pods will prove less difficult to extract than high sugar pods.

Boiling-Water Treatment

This treatment is effective for legumes with seed-coat dormancy, It requires no special equipment and is convenient, easy to apply, and is relatively safe. The seeds may be placed in wire baskets or cloth sacks and dipped in boiling water for the requisite time--usually one to five minutes. However, a better procedure is to bring the required amount of water (usually two to three times the bulk volume of the seeds) to a boil; then remove it from the heat and pour the entire quantity of seeds to be treated into it. The seeds are allowed to soak as the water gradually cools to room temperature. The proper relationship between the weight of seeds and the volume of water can be determined by a few tests. The risk lies in using too much water and thereby cooking the seeds. When the boiling-water treatment is effective, the seeds imbibe water and begin to swell as the water cools. When the treatment is properly applied, it will be found that some seeds have escaped the treatment and remain unswollen even after prolonged soaking. If there are many such seeds, they may be separated from the swollen seeds and treated again. The swollen seeds, if viable, will germinate normally. Seeds that have been scarified by hot water cannot be dried and stored but must be sown immediately.

Mechanical Scarification

One of the simplest and most direct methods of mechanical scarification is to clip a small notch in the seed with a razor blade or sharp knife. Do not cut the radicle. If there is doubt as to which end has the radicle, notch the seed on the side. This allows the seed to imbibe water, and as it does it will swell and rupture the seed coat permitting normal germination.

ATTACHMENT III

INOCULATION

Legumes, such as those included in these trials, have the unique ability to associate with the soil bacteria Rhizobium. The rhizobia form nodules resembling galls on the plant roots and can take nitrogen from the air and convert or "fix" the nitrogen so that it becomes available for the plant to use. Inoculating legume seeds with the appropriate rhizobia will ensure early and effective nodulation.

The rhizobial strains contained in the accompanying inoculum were selected by researchers at the University of Hawaii's NifTAL Project as being effective for the range of tree species included in these trials. In order to obtain maximum advantage from the inoculum provided, each cooperating researcher should do the following:

- Check the freshness of the inoculum. The expiration date is stamped on each packet. The inoculum is a living culture of root-nodule bacteria, which are killed by drying and also by high temperatures. Make sure that this culture has been stored continuously under refrigeration upon receipt. Poor storage conditions can cause nodulation failure by reducing the number of viable bacteria in the inoculum.

- Use the inoculum before the expiration date. Do not carry it over to another year. The number of bactéria that survive will be too low for effective nodulation.

- The quantity of inoculum provided is well in excess of that actually required for these trials. The use of the entire quantity will, however, better assure effective nodulation. It is suggested that the inoculum be applied as follows:

    1. Separate the two-fifths of the seed in each seedlot to be planted in the two inoculated trial blocks.

    2. Place the seed in 20 small containers, one for each accession, and add 1/20th of the inoculum to each container.

    3. Add sufficient water to thoroughly moisten the seed so that the peat will stick to it. Do not use excessive quantities of water.

    4. Place the inoculated seed in growth containers and cover the inoculated seed with soil.

Please contact the National Research Council immediately should additional quantities of inoculum be required.

ATTACHMENT IV

SOIL SAMPLES FROM TRIAL SITES

Purpose

Soils from field plots of the NRC-sponsored species trials are to be collected and analyzed at USDA - Beltsville for the following properties:

1. *Rhizobium* population levels, including levels of specific isolates for each host legume in the species trial.

2. The nitrogen-fixing effectiveness of such isolates as compared with isolates contained within the peat inoculum supplied to cooperators.

3. Soil chemical properties, such as pH, mineralizable nitrogen, available phosphorous, texture, and if possible, the level of mycorrhizal spores.

Procedure for obtaining soil samples.

Each cooperator will be provided with two mailing cartons (20 x 9 cm) for shipment of soil. From the field plot where the species are to be planted, eight to 10 soil sub-samples should be obtained from across the whole plot, such that they are approximately equidistant from each other. Each subsample would be a shovel-full of soil, (from a clean shovel) representing the uppermost [illegible] cm of soil. These subsamples should be placed in a clean wheelbarrow (or other device) large enough to hold all eight to 10 subsamples. The subsamples should then be thoroughly mixed together. Finally, some of the mixed sample is used to fill the plastic bag inside the two mail containers to their full capacity.

Mailing the cartons

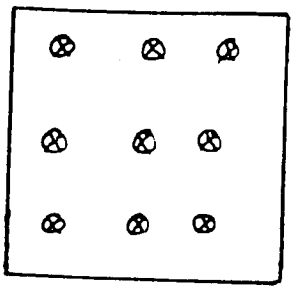
To assure delivery to Beltsville, each container must have an address label and a separate soil permit label (white) with the heading:

"IMPORTATION AUTHORIZED"

The address label should read:

Dr. H. H. Keyser
USDA - ARS - NFSGL
Bldg. 011, HH-19, BARC-W
Beltsville, MD 20705
USA

1. Obtain subsamples across whole plot.

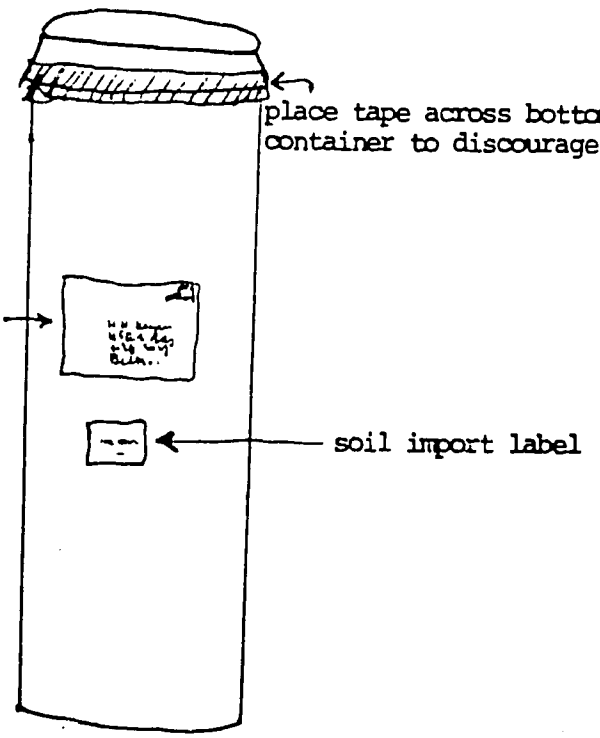


⊗ = one soil subsample, top 15 cm of soil

Field plot for NAS-sponsored species trial.

2. Mix subsamples together in wheelbarrow or other large container.

3. Fill plastic bags with mailing containers, ship to Beltsville.



ATTACHMENT V

SUPERABSORBENT APPLICATION

Enclosed in the trial packets are superabsorbent products provided by Industrial Services International of Bradenton, Florida.

It is recommended that the superabsorbent (terra-sorb) be used, as recommended in the enclosed instructions, in connection with one of the inoculated trial blocks and one of the uninoculated blocks.

Sketch No. 1

NRC-SPONSORED SPECIES TRIALS

RANDOMIZED COMPLETE BLOCK DESIGN

NAS SAHEL
RANDOMISED COMPLETE BLOCK DESIGN - 5 REPS, 20 PLOTS/REP
SITE 1

REPLIC 1	4	3	10	2	15	7	6	19	15	20
	12	8	11	18	17	5	1	13	14	9
REPLIC 2	5	9	15	6	17	4	7	16	18	1
	19	12	8	11	14	20	2	13	10	3
REPLIC 3	1	4	9	16	13	18	5	6	12	20
	8	19	15	10	17	14	3	7	2	11
REPLIC 4	17	13	5	15	10	3	1	4	9	14
	20	2	18	8	19	11	16	7	12	6
REPLIC 5	20	3	16	18	13	12	17	1	15	2
	10	19	14	5	7	8	4	9	6	11

Design - Randomized Complete Block

Replications - Five

Accessions - 20

Total number of trees in field - 2,500 (double in nursery)

Number of trees per accession in field - 125 (double in nursery)

Number of individual trees per replication - 500

Number of trees per accession per replication - 25

Plot layout - Squares of five trees across, five trees down
(20 plots per replication)

Spacing between trees - Three meters

Approximate size of trial - 2.5 hectares

Approximate size of replication - 5,000 sq. meters

Form No. 1

NRC SPONSORED SPECIES TRIALS

SPECIES TRIAL SITE DESCRIPTION FORM

Date: _____

Supervisor: _____

Country: _____

Province: _____

District: _____

Site: _____

Lat: _____ Long: _____ Alt: _____

Topography: Flat/hilly

Slope: steep/medium/gentle

Soil: Deep/shallow/itermediate

Drainage: _____

_____

Stoniness: _____

Texture: _____

Other important features, e.g. salinity, extreme alkalinity: _____

_____

pH: Acid/neutral/alkaline

Nearest weather station: _____(Lat:____°____'; Long____°____';

Alt:_____m)

Mean climatic data :	J	F	M	A	M	J	J	A	S	O	N	D	Total Years
Rainfall mean (mm)													
Monthly mean max. temp. (°C)													
Monthly mean min. temp. (°C)													
Mean monthly temp. (°C)													

Original vegetation type: _____

_____

_____

Overstorey: _____

_____

_____

Understorey: _____

_____

_____

Ground flora: _____

_____

_____

Land use history: _____

_____

_____

_____

_____

Principal features affecting growth: _____

_____

_____

_____

_____

_____

_____

_____

Country: _____ Design: _____

Site: _____ Number of replications: _____

Date of Establishment: _____ Number of trees per plot: _____

Number of Accession: _____ Spacing: _____ x _____ m

Seedlot Number	S p e c i e s	Country of Origin	Provenance	Identification Number

Form No. 2

NRC SPONSORED SPECIES TRIALS

NURSERY RECORD FORM

Country: _____ Species: _____

Site: _____ Seedlot number: _____

Supervisor: _____ Identification number: _____

Types of information to be recorded:

- Filling of containers: type, size of containers; description of soil mix used
- Laying out of containers: refer to design of experiment, method of identification
- Sowing: list species, identification numbers, and replication numbers
- Weeding: list methods used, dates
- Fertilizing: list fertilizers used, dosage, dates, method of application
- Insect and pest control: list chemicals used, dosage, dates, method of application
- Assessments undertaken (germination, survival, etc.)
- Transportation to planting site: method, date, duration
- Watering schedule
- Miscellaneous observations; unusual events

(Fill in one form per accession)

Details of Operation or Observation	Date	Initials

Form No. 3

NRC SPONSORED SPECIES TRIALS

GERMINATION RECORD FORM

Country: _____ Species: _____

Site: _____ Provenance: _____

Supervisor: _____ Seedlot Number: _____

Date Sown: _____ Identification Number: _____

Date Inoculated: _____

(Please fill in one form per accession)

Date of Observation	Number of Seeds Sown	Number of Seeds Germinated	Plant %	Observations	Initials

Form No. 4

NRC SPONSORED SPECIES TRIALS

NURSERY ASSESSMENT FORM

Country: _____ Date sown: _____

Site: _____ Date assessed: _____

Species: _____ Assessed by: _____

Provenance: _____ Number of seeds germinated: _____

Seedlot number: _____ Number of seedlings survived: _____

Identification number: _____ Survival percentage: _____

(Assessments should be made approximately one week before outplanting, probably the third week in July.)
Please fill in one form per accession

Seedling number	Height (cm)	Observations (vigor, color, health, etc.)

Form No. 5

NRC SPONSORED SPECIES TRIALS

FIELD RECORD FORM

Country: _____ Species: _____

Site: _____ Seedlot Number: _____

Supervisor: _____ Identification Number: _____

Average height at outplanting
(to nearest centimeter): _____

Types of information to be recorded:

- Site preparation: brief description of each phase; methods, timing, etc.
- Demarcation of experiment in the field: indicate methods of identification of species in the field, staking, etc.
- Planting method
- Replacements: list number of replacements per accession, replication number and position; give reasons for failure if known
- Weeding: dates, methods
- Insecticides, fungicides applied: dates, types, dose/rates, reasons for application
- Miscellaneous observations; unusual events

(Fill in one form per accession)

Details of Operation and Observations	Date	Initials

Field Record Form (cont'd)

Details of Operation and Observations	Date	Initials

Form No. 6

NRC SPONSORED SPECIES TRIALS

FIELD ASSESSMENT FORM

Country: _____ Accession: _____

Site: _____ Provenance: _____

Date of establishment: _____ Identification number: _____

Date of assessment: _____ Replication number: _____

Assessed by: _____

(Assessments should be made after first month and yearly thereafter)
Please fill in one form per plot

Tree Number	Height at outplanting (cm)	Height (cm)	D A M A G E	O B S E R V A T I O N S
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				

APPENDIX D

ACOS SEEDLOT SHIPMENTS UNDER AID GRANT AFR-0929-G-SS-1104-00
(As of May 23, 1983)

COUNTRY AND RECIPIENT	ACCESSION
Cape Verde	
Ministry of Rural Development (H. Soares)	*Phaseolus acutifolius* *Zea mays*
USAID (R. Pellek)	*Acacia albida* (82/598) *A aneura* (12791) *A. cambagei* (13485) *A. ligulata* (13425) *A. nilotica* subsp. *adstringens* (81/443) *A. nilotica* subsp. *tomentosa* (82/597) *A senegal* (82/593) *A. tortilis* subsp. *raddiana* (82/599) *A. tumida* (11496) *A. victoriae* (13271) *Conocarpus lancifolius* *Cordeauxia edulis* *Geoffroea decorticans* *Leucaena leucocephala* (K8) *L. leucocephala* (K30) *L. leucocephala* (K500) *Parkinsonia aculeata* (80/258) *Phaseolus acutifolius* *Prosopis* hybrid (PC 004) *Prosopis* hybrid (PC 005) *P. africana* (106) *P. alba* (JO 053) *P. alba* (0166) *P. alba* (0388) *P. glandulosa* var. *glandulosa* (PG 032) *P. juliflora* (79/194) *P. velutina* (PC 035) *P. velutina* (0457) *Stylosanthes scabra* (Q10042)

Chad

USAID (J. Woods)	Amaranthus cruentus (R104) A. hypochondriacus (R103) Panicum sonorum Phaseolus acutifolius Tylosema esculentum Zea mays

The Gambia

Department of Forestry (B. Taal)	Acacia mangium Calliandra calothyrsus Leucaena leucocephala (K8) Sesbania grandiflora
Gambian-German Forestry Project (H. Forster)	Calliandra calothyrsus Leucaena leucocephala (K67) Sesbania grandiflora
USAID (S. Deffendol)	Calliandra calothyrsus Leucaena leucocephala (K8) Sesbania grandiflora
USAID (M. Madland)	Leucaena leucocephala (K8) L. leucocephala (K67) Psophocarpus tetragonolobus

Mali

British Volunteers (P. Lambert)	Simmondsia chinensis
Eaux et Forêts (S. Kanouté)	Eucalyptus brockwayi (12266) E. camaldulensis (12184) E. camaldulensis (12346) E. camaldulensis (12476) E. intertexta (11736) E. melanophloia (13158) E. microtheca (12846) E. microtheca (13360) E. occidentalis (9806) E. oleosa var. oleosa (12310) E. terminalis (11966) E. tessellaris (12967) E. torquata (10106) Phaseolus acutifolius (two shipments) Simmondsia chinensis

ICRISAT (J. Scheuring)	Amaranthus cruentus (R104) A. hypochondriacus (R103) Panicum sonorum Phaseolus acutifolius (two shipments) P. coccineus Psophocarpus tetragonolobus (Tpt-1) Tylosema esculentum Zea mays (two shipments)
ICRISAT (A. Sow)	Geoffroea decorticans Panicum sonorum Tarchonanthus camphoratus Tylosema esculentum
ILCA (P. Gosseye)	Atriplex Canescens A. nummularia Centrosema sp. (65967) C. pascuorum (55697) Desmanthus virgatus (65947) Leucaena leucocephala (K500) Macroptilium atropurpureum (85002) M. martii (49780) M. martii (55783) Phaseolus acutifolius P. filiformis (85005) Stylosanthes scabra (Q10042) S. scabra (Fitzroy) S. scabra (Seca) S. sympodialis (67703) S. hamata (Verano) Tarchonanthus camphoratus Tylosema esculentum Zea mays
Peace Corps (M. Ahearn)	Adansonia digitata (82/603) Anogeissus leiocarpus (82/571) Balanites aegyptiaca (82/602)
Peace Corps (D. Clark)	Acacia farnesiana Amaranthus cruentus Caesalpinia gilliesii Cassia wislizenii Cercidium floridum Chilopsis linearis Cordeauxia edulis Dasylirion wheeleri Dodonaea viscosa Encelia farinosa Leucaena leucocephala (K8) Melia azedarach Pachycereus pecten-arboriginum

	Prosopis chilenses Salvia greggii Simmondsia chinensis Yucca elata Zea mays
Sahel Institute (O. Sidibé)*	Amaranthus cruentus (R104) A. hypochondriacus (R102) Panicum sonorum Phaseolus acutifolius (two shipments) P. coccineus Psophocarpus tetragonolobus (Tpt-1) Tylosema esculentum Zea mays (two shipments)
USAID (J. Anderson)	Acacia albida (82/598) A aneura (12791) A. cambagei (13485) A. ligulata (13425) A. nilotica subsp. adstringens (81/443) A. nilotica subsp. tomentosa (82/597) A. senegal (82/593) A. tortilis subsp. raddiana (82/599) A. tumida (11496) A. victoriae (13271) Calliandra calothyrsus Leucaena leucocephala (K8) L. leucocephala (K30) L. leucocephala (K67) L. leucocephala (K500) Parkinsonia aculeata (80/258) Prosopis hybrid (PC 004) Prosopis hybrid (PC 005) P. africana (106) P. alba (JO 053) P. alba (0166) P. alba (0388) P. glandulosa var. glandulosa (PG 032) P. juliflora (79/194)

*One-half of all "new crop" seed was given to the institute for redistribution within the Sahel.

	Prosopis velutina (PC 035) P. velutina (0457) Sesbania grandiflora

Mauritania

Agricultural Service (H. Lam)	Amaranthus cruentus (R104) A. hypochondriacus (R103) Panicum sonorum Phaseolus acutifolius Tylosema esculentum Zea mays
Lutheran World Federation/ Service for the Protection of Nature (G. ten Velde/ M. Abbey)	Acacia albida (82/598) Acacia aneura (12791) A. cambagei (13485) A. ligulata (13425) A. nilotica subsp. adstringens (81/443) A. nilotica subsp. tomentosa (82/597) A. senegal (82/593) A. tortilis subsp. raddiana (82/599) A. tumida (11496) A. victoriae (13271) Atriplex canescens A. nummularia Eucalyptus camaldulensis (12184) E. camaldulensis (12346) E. camaldulensis (13476) Geoffroea decorticans Leucaena leucocephala (K8) L. leucocephala (K30) L. leucocephala (K500) Parkinsonia aculeata (80/258) Prosopis hybrid (PC 004) Prosopis hybrid (PC 005) P. africana (106) P. alba (JO 053) P. alba (0166) P. alba (0388) P. glandulosa var. glandulosa (PG 032) P. juliflora (79/194) P. velutina (PC 035) P. velutina (0457) Simmondsia chinensis Stylosanthes hamata S. scabra (Q10042) S. scabra (Fitzroy) S. scabra (Seca) S. sympodialis

USAID (J. Falconi)	Acacia farnesiana Caesalpinia gilliesii Carnegiea gigantea Cassia artemisioides C. wislizenii Cercidium floridum Chilopsis linearis Dasylirion wheeleri Dodonaea viscosa Echinocereus Boyce-thompsonii Encelia farinosa Ferocactus wislizenii Idria columnaris Leucaena leucocephala L. retusa Lysiloma microphylla Melia azedarach (two shipments) Orthocarpus purpurasiens Pachycereus pecten-arboriginum Penstemon parryi Proboscidea sp. Prosopis chilensis P. juliflora var. torreyana Salvia greggii Stylosanthes guianensis S. hamata (Verano) S. scabra (Fitzroy) S. scabra (Seca) S. viscosa Yucca elata
USAID (M. Goldensohn)	Acacia albida (82/598) Acacia aneura (12791) A. cambagei (13485) A. ligulata (13425) A. nilotica subsp. adstringens (81/443) A. nilotica subsp. tomentosa (82/597) A. senegal (82/593) A. tortilis subsp. raddiana (82/599) A. tumida (11496) A. victoriae (13271) Leucaena leucocephala (K8) L. leucocephala (K30) L. leucocephala (K500) Parkinsonia aculeata (80/258) Prosopis hybrid (PC 004) Prosopis hybrid (PC 005) P. africana (106) Prosopis alba (JO 053) P. alba (0166) P. alba (0388)

	P. glandulosa var. glandulosa (PG 032) P. juliflora (79/194) P. velutina (PC 035) P. velutina (0457)
USAID (A. Hirsch)	Amaranthus cruentus (R104) Phaseolus acutifolius Zea mays
USAID (R. Illick)	Melia azedarach
USAID (S. Seefeldt)	Acacia albida (82/598) A. aneura (12791) A. cambagei (13485) A. ligulata (13425) A. nilotica subsp. adstringens (81/443) A. nilotica subsp. tomentosa (82/597) A. senegal (82/593) A. tortilis subsp. raddiana (82/599) A. tumida (11496) A. victoriae (13271) Leucaena leucocephala (K8) L. leucocephala (K30) L. leucocephala (K500) Parkinsonia aculeata (80/258) Prosopis hybrid (PC 004) Prosopis hybrid (PC 005) P. africana (106) P. alba (JO 053) P. alba (0166) P. alba (0388) P. glandulosa var. glandulosa (PG 032) P. juliflora (79/194) P. velutina (PC 035) P. velutina (0457)
USAID (J. Wedberg)	Phaseolus acutifolius Gray Stylosanthes guianensis S. hamata (Verano) S. scabra (Fitzroy) S. scabra (Seca) Zea mays
Niger	
USAID (J. Heerman)	Acacia adsurgens (13738) A. albida (82/598) Acacia aneura (12791) A. cambagei (13487) A. coriaecea (13768) A. cowleana (13774)

A. estrophilata (13799)
A. holosericea (13771)
A. latzii (13780)
A. monticola (13773)
A. nilotica subsp. adstringens (82/443)
A. senegal (82/594)
A. tenuissima (13800)
A. tortilis subsp. raddiana (82/599)
A. validinervia (13797)
A. victoriae
Leucaena leucocephala (K67)
Prosopis africana (82/672)
P. alba (PC 062)
P. chilensis
P. glandulosa var. glandulosa (PC 032)
P. juliflora (79/194)
P. velutina (PC 035)

Peace Corps (D. Hart)

Acacia aneura (12791)
A. berlandieri
A. nilotica subsp. adstringens (81/443)
A. raddiana (82/599)
Amaranthus cruentus (R104)
A. hypochondriacus (R103)
Argania spinosa (77307)
Eucalyptus brockwayi (12266)
E. oleosa var. oleosa (12310)
Geoffroea decorticans (BE-7463)
Leucaena leucocephala (K8)
L. leucocephala (K30)
L. leucocephala (K67)
Macroptilium atropurpureum (Siratro)
Mitragyna inermia (82/604)
Phaseolus acutifolius
Prosopis alba (0166)
P. velutina (0457)
Simmondsia chinensis
Tarchonanthus camphoratus
Tylosema esculentum
Zea mays

Swiss Development Cooperation (A. Schenker)

Acacia albida (82/598)
A. aneura (12791)
A. cambagei (13485)
A. ligulata (13425)
Acacia nilotica subsp. adstringens (81/443)
A. nilotica subsp. tomentosa (82/597)
A. senegal (82/593)
A. tortilis subsp. raddiana (82/599)
A. tumida (11496)

A. victoriae (13271)
Atriplex nummularia (WA 1981) (two shipments)
Conocarpus lancifolius (two shipments)
Geoffroea decorticans (BE7463) (two shipments)
Leucaena leucocephala (K8)
L. leucocephala (K30) (three shipments)
L. leucocephala (K500)
Parkinsonia aculeata (80/258)
Prosopis sp. (PC 004)
Prosopis sp. (PC 005)
P. africana (106)
P. alba (JO 053)
P. alba (0166)
P. alba (0388)
P. glandulosa var. glandulosa (PC 032) (three shipments)
P. juliflora (79/194)
P. velutina (PC 035)
P. velutina (0457)
Simmondsia chinensis (two shipments)
Tarchonanthus camphoratus (two shipments)
Tylosema esculentum (two shipments)

USAID (J. Heermans)

Acacia albida (82/598)
A. aneura (12791)
A. cambagei (13485)
A. ligulata (13425)
A. nilotica subsp. adstringens (81/443)
A. nilotica subsp. tomentosa (82/597)
A. senegal (82/593)
A. tortilis subsp. raddiana (82/599)
A. tumida (11496)
A. victoriae (13271)
Leucaena leucocephala (K8)
L. leucocephala (K30)
L. leucocephala (K500)
Parkinsonia aculeata (80258)
Prosopis hybrid (PC 004)
Prosopis hybrid (PC 005)
P. africana (106)
Prosopis alba (JO 053)
P. alba (0166)
P. alba (0388)
P. glandulosa var. glandulosa (PG 032)
P. juliflora (79/194)
P. velutina (PC 035)
P. velutina (0457)

USAID/ILPP (R. Bement)	Atriplex canescens A. nummularia (WA-1981) Centrosema sp (65967) C. brasilianum (55696) C. pascuorum (55697) Desmanthus virgatus (56947) Leucaena leucocephala (K500) Macroptilium atropurpureum (85002) M. martii (49780) M. martii (55783) Phaseolus acutifolius P. filiformis Stylosanthes hamata (Verano) S. scabra (Q10042) S. scabra (Fitzroy) S. scabra (Seca) S. sympodialis (67703) Tarchonanthus camphoratus Tylosema esculentum
USAID (J. Johnson)	Amaranthus cruentus Phaseolus acutifolius Zea mays

Senegal

German Forestry Mission (C. Dering)	Calliandra calothyrsus Leucaena leucocephala (K67) Prosopis alba (JO 053) P. alba (0388) P. alba (0166) P. alba (a) P. alba (b) P. glandulosa var glandulosa (PC 032) P. juliflora P. velutina (PC 035) P. velutina (0457) P. velutina (162) P. velutina (163) P. velutina (164) P. velutina (165) Prosopis velutina (171) P. velutina (172) Sesbania grandiflora Simmondsia chinensis
Philippe Hemery	Phaseolus acutifolius
ISRA/CNRF (C. Bailly)	Calliandra calothyrsus Leucaena leucocephala (K67) Sesbania grandiflora

ISRA/CNRF (O. Hamel)

Acacia adsurgens (13738)
A. aneura (12791)
A. cambagei (13768)
A. coriacea (13768)
A. cowleana (13774)
A. estrophiolata (13799)
A. farnesiana (11147)
A. holosericea (13771)
A. latzii (13780)
A. monticola (13773)
A. senegal
A. tenuissima (13800)
A. validinervia (13797)
A. victoriae (13271)
Argania spinosa
Atriplex canescens
A. nummularia (WA-1981)
Centrosema pascuorum (55697)
Conocarpus lancifolius
Dodonea angustissima (13753)
Eucalyptus melanophloia (13158)
E. occidentalis (9806)
E. terminalis (11966)
Geoffroea decorticans (BE-7463)
Leucaena leucocephala (K67)
Melaleuca lasiandra (13752)
Prosopis alba (0166)
P. alba (0388) (two shipments)
P. alba (PC 062)
P. chilensis
P. glandulosa var. glandulosa (PC 032)
P. glandulosa var. glandulosa
P. tamarugo
P. velutina (PC 035)
P. velutina (0457) (two shipments)
Simmondsia chinensis

ISRA/LNERV (G. Roberge)

Atriplex canescens (two shipments)
Centrosema sp. (65967)
Centrosema brasilianum (55696) (two shipments)
C. pascuorum (55697) (two shipments)
Desmanthus virgatus
Leucaena leucocephala (K8) (two shipments)
Macroptilium atropurpureum (85002) (two shipments)
M. martii (49780) (two shipments)
M. martii (55783) (two shipments)
Panicum sonorum
Phaseolus acutifolius

	P. filiformis (85005) Stylosanthes guianensis S. hamata (Verano) (two shipments) S. scabra (Q10042) (two shipments) S. scabra (Fitzroy) (two shipments) S. scabra (Seca) (two shipments) S. sympodialis (67703) (two shipments) S. viscosa (34094) Tarconanthus camphoratus (two shipments) Tylosema esculentum (two shipments)
Senegalese Forest Service (El-Hadji Sène)	Acacia linarioides A. salicina (13379) Argania spinosa Calliandra calothyrsus Chilopsis linearis Dasylirion wheeleri Encelia farinosa Geoffroea decorticans Leucaena leucocephala Orthocarpus purpurasiens Salvia greggii Sesbania grandiflora Tarchonanthus camphoratus Yucca elata
Swiss Technical Cooperation (E. Locher)	Acacia albida (82/598) A. aneura (12791) A. cambagei (13485) A. ligulata (13425) A. nilotica subsp. adstringens (81/443) A. nilotica subsp. tomentosa (82/597) A. senegal (82/593) A. tortilis subsp. raddiana (82/599) A. tumida (11496) Acacia victoriae (13271) Atriplex canescens A. nummularia (WA-1981) Centrosema brasilianum (55696) C. pascuorum (55697) Leucaena leucocephala (K8) L. leucocephala (K30) L. leucocephala (K500) Macroptilium atropurpureum (Siratro) M. martii (49780) Parkinsonia aculeata (80/258) Phaseolus acutifolius Prosopis hybrid (PC 004) Prosopis hybrid (PC 005) P. africana (106) P. alba (JO 053)

	P. alba (0166) P. alba (0388) P. glandulosa var. glandulosa (PG 032) P. juliflora (79/194) P. velutina (PC 035) P. velutina (0457) Stylosanthes hamata (Verano) S. scabra (Q10042) S. scabra (Fitzroy) S. scabra (Seca) S. sympodialis (67703) Tarchonanthus camphoratus Tylosema esculentum
USAID (D. Diop)	Atriplex canescens A. nummularia (WA-1981) Centrosema brasilianum (55696) C. pascuorum (55697) Tylosema esculentum
USAID (P. Freeman)	Carnegiea gigantea Chilopsis linearis Cordeauxia edulis Dodonea viscosa Echinocereus Boyce-thompsonii Ferocactus wislizenii Idria columnaris Melia azedarach Salvia greggii Stylosanthes guianensis S. hamata (verano) S. scabra (Seca) S. viscosa (34094) Yucca elata
USAID (D. Gibson)	Acacia albida (82/598) A. aneura (12791) A. cambagei (13485) A. ligulata (13425) A. nilotica subsp. adstringens (81/443) A. nilotica subsp. tomentosa (82/597) A. senegal (82/593) A. tortilis subsp. raddiana (82/599) A. tumida (11496) A. victoriae (13271) Leucaena leucocephala (K8) L. leucocephala (K30) L. leucocephala (K500) Parkinsonia aculeata (80/258) Prosopis hybrid (PC 004) Prosopis hybrid (PC 005)

	P. africana (106) P. alba (JO 053) P. alba (0166) P. alba (0388) P. glandulosa var. glandulosa (PG 032) P. juliflora (79/194) P. velutina (PC 035) P. velutina (0457)
USAID (R. MacAlister)	Psophocarpus tetragonolobus
USAID (M. Niamir)	Acacia albida (82/598) A. farnesiana (11147) A. linarioides (11506) A. tortilis subsp. raddiana (82/599) Atriplex canescens A. nummularia (WA-1981) Centrosema brasilianum (55696) Eucalyptus camaldulensis (12184) Geoffrea decorticans (BE 7463) Leucaena leucocephala (K8) L. leucocephala (K30) Macroptilium atropurpureum (85002) Panicum sonorum Parkinsonia aculeata (80/258) Phaseolus acutifolius Prosopis alba (0166) P. juliflora (79/194) Simmondsia chinensis Stylosanthes hamata (Verano) S. scabra (Q10042) Tarchonanthus camphoratus
USAID (C. Steedman)	Acacia mangium Calliandra calothyrsus Leucaena leucocephala (K8) Sesbania grandiflora
Upper Volta	
IRAT (Mr. Duque)	Amaranthus cruentus (R104) A. hypochonriacus (R103) Panicum sonorum Phaseolus acutifolius P. coccineus Psophocarpus tetragonolobus (Tpt-1) Tylosema esculentum Zea mays

USAID (R. Meyer)	Phaseolus acutifolius Simmondsia chinensis Tylosema esculentum
United States Embassy (Ambassador J. Walker, Jr.)	Phaseolus acutifolius Zea mays

Shipments to Non-Sahelian Countries

Australia

CSIRO/Australia (R. Reid)	Panicum sonorum

Belgium

Export Nurseries (H. van Hulle)	Simmondsia chinensis

Brazil

IPASE-COXIPO (G. Assis)	Acacia berlandieri

Burundi

USAID (H. Fisher)	Calliandra calothyrsus Leucaena leucocephala (K8) L. leucocephala (K30) L. leucocephala (K67) L. leucocephala (K500) Sesbania grandiflora

China (PRC)

Lanzhou Institute of Desert Research (Z. Zenda)	Acacia albida (82/598) A. nilotica var. adansonii A. senegal (82/593) Leucaena leucocephala (K8) L. leucocephala (K500) Parkinsonia aculeata (80/258) Prosopis africana (106) P. alba (0166) P. glandulosa var. glandulosa (PC 032) P. juliflora (79/194) P. velutina (0457)

Costa Rica

Rancho las Manchas (N. Siegel)	Acacia albida (82/598) A. senegal Amaranthus cruentus (R104)

	A. hypochondriacus (R103) Centrosema brasilianum (55696) Eucalyptus camaldulensis (12346) E. camaldulensis (13476) Leucaena leucocephala (K8) L. leucocephala (K30) L. leucocephala (K67) L. leucocephala (K500) Macroptilium atropurpureum (Siratro) Stylosanthes hamata (Verano) S. scabra (Fitzroy) S. scabra (Q10042) S. scabra (Seca) S. sympodialis (67703)

England

Royal Botanic Gardens (G. Wickens)	Amaranthus cruentus (R104) A. hypochondriacus (R103) Argania spinosa (77307) Atriplex canescens Centrosema brasilianum (55696) C. pascuorum (55697) Geoffroea decorticans (BE-07463) Macroptilium atropurpureum (Siratro) M. martii (49780) Stylosanthes hamata (Verano) S. scabra (Q10042) S. scabra (Fitzroy) Stylosanthes scabra (Seca) S. sympodialis (67703) Tarchonanthus camphoratus Tylosema esculentum

Gabon

Ministry of Planning (E. Kron)	Calliandra calthyrsus Leucaena leucocephala (K67) Sesbania grandiflora

Ghana

Northern Region Rural Integrated Program (P. McLoughlin)	Calliandra calothyrsus Leucaena leucocephala Sesbania grandiflora Zea mays

Haiti

Peace Corps (W. Granger)	Acacia nilotica subsp. tomentosa (82/597) Amaranthus hypochondriacus (R103) Anogeissus leiocarpus (82/571) Argania spinosa (77/307) Balanites aegyptiaca (82/602) Eucalyptus camaldulensis (12346) E. melanophloia (13158) E. microtheca (12846) Leucaena leucocephala (K8) L. leuococephala (K67) Phaseolus acutifolius Prosopis africana (106) P. juliflora (79/194) P. tamarugo P. velutina (0457) Simmondsia chinensis Stylosanthes scabra (Seca) Tarchonanthus camphoratus Tylosema esculentum

Honduras

E. Falck	Zea mays

Israel

Ben-Gurion University (J. Aronson)	Acacia albida (82/598) A. nilotica subsp. [illegible]ringens (81/443) Acacia senegal Anogeissus leiocarpus (82/571) Argania spinosa (77307) Geoffroea decorticans (BE-7463) Prosopis africana (106) P. alba (0166) P. alba (0388) P. glandulosa var. glandulosa Tarchonanthus camphoratus Tylosema esculentum

Ivory Coast

USAID (G. Anders)	Zea mays

Jordan

USAID (K. Laurent)	Acacia albida (82/598)

Kenya

B.A.T. Kenya Ltd. (C. Gaitho)	Acacia albida (82/598) Eucalyptus brochwayi (12266) E. camadulensis (13476) E. microtheca (12846) E. occidentalis (9806) Leucaena leucocephala (K8) Prosopis alba (0166)
ICRAF (L. Buck - see following)	
Mennonite Central Committee (W. Teel)	Anogeissus leiocarpus (82/571) Prosopis alba (0166) Tarchonanthus camphoratus
University of Nairobi (W. Mathai via R. Ford at Clark University)	Acacia mangium Calliandra calothrysus Leucaena leucocephala Sesbania grandiflora

Lebanon

Mennonite Central Committee (sent via L. Keeney)	Acacia albida (82/598)

Nigeria

Federal Department of Forestry (M. Oyebo)	Simmondsia chinensis

Pakistan

National Agriculture Research Centre (G. Sandhu)	Eucalyptus camaldulensis (12184) E. camaldulensis (12346) E. camaldulensis (13476) Parkinsonia aculeata Prosopis alba (0166) (two shipments) P. alba (0388) P. glandulosa var. glandulosa P. juliflora (79/194) P. tamarugo P. velutina (0457)

Somalia

R. Kankis	Amaranthus cruentus (R104) A. hypochondriacus (R103) Leucaena leucocephala (K8) L. leucocephala (K30) L. leucocephala (K500) Psophocarpus tetragonolobus (Tpt-1)

	P. tetragonolobus (F-452) Tylosema esculentum

Tanzania

University of Dar es Salaam (J. Hall)	Prosopis alba (0166)

'Uman

Tetra Tech International (J. Bannigan)	Amaranthus cruentus (R104) A. hypochondriacus (R103) Panicum sonorum Phaseolus acutifolius (two shipments) P. coccineus Psophocarpus tetragonolobus (Tpt-1) Tylosema esculentum Zea mays (two shipments)

United States

Desert Botanical Garden, Phoenix (H. Gentry)	Argania spinosa (77307) Cordeauxia edulis (two shipments) C. edulis Ye-eb
Meals for Millions (G. Nabhan)	Balanites aegyptiaca (82/602) Macroptilium atropurpureum (Siratro) Prosopis glandulosa var. glandulosa P. tamarugo Tylosema esculentum
University of Florida (H. Popenoe)	Zea mays
University of Hawaii (J. Halliday)	Acacia albida (82/598) A. aneura (12791) A. farnesiana (L.) Willd. (11147) A. linarioides (11506) A. nilotica subsp. adstringens (81/443) A. nilotica subsp. tomentosa (82/597) A. salicina (13379) A. senegal (82/593) A. tortilis subsp. raddiana (82/599) Parkinsonia aculeata L. (80/258) Prosopis africana (106) P. alba (0166) P. alba (0388) P. glandulosa var. glandulosa P. julifora (79/194) P. velutina (0457)

USAID (R. Dodson)	Centrosema pascuorum (55697) C. brasilianum (55696) Macroptilium atropurpureum (Siratro) M. martii (49780) Stylosanthes scabra (Q10042) S. scabra (Fitzroy) S. scabra (Seca) S. sympodialis Tylosema esculentum
USDA/Beltsville (J. Duke)	Acacia albida (82/598) A. farnesiana (11147) A. nilotica subsp. adansonii (81/443) A. nilotica subsp. tomentosa (82/597) A. tortilis subsp. raddiana (82/599) A. senegal (82/593) Parkinsonia aculeata (80/258) Prosopis alba (0166) P. alba (0388) P. glandulosa var. glandulosa P. tamarugo
USDA (C. Gunn)	Geoffroea decorticans
USDA (H. Keyser)	Acacia albida (82/598) A. aneura (12791) A. nilotica subsp. adansonii (82/597) A nilotica subsp. tomentosa (82/597) A. senegal (82/593) A. tortilis subsp. raddiana (82/599) Leucaena leucocephala (K8) Parkinsonia aculeata (80/258) Prosopis africana (106) P. alba (0166) P. alba (0388) P. glandulosa var. glandulosa (PC032) P. juliflora (79/194) P. velutina (0457)
USDA/Pasadena (B. Tisserat)	Acacia albida (82/598) A. nilotica subsp. tomentosa (82/597) A. tortilis subsp. raddiana (82/599) Adansonia digitata (82/603) Anogeissus leiocarpus (82/571) Argania spinosa (77/307) Balanites aegyptiaca (82/602) Conocarpus lancifolius Mitragyna inermis (82/604) Prosopis africana (106) Tarchonanthus camphoratus Tylosema esculentum

APPENDIX E

COMPREHENSIVE LIST OF SPECIES
PROVIDED FOR RESEARCH IN THE SAHEL

Species	Number of Accessions	Common Name
Acacia adsurgens	1	Mulga
A. albida	1	Apple-Ring Acacia
A. aneura	1	Mulga
A. berlandieri	1	Huajillo
A. cambagei	2	Gidgee
A. coricea	1	Wirewood
A. cowleana	1	
A. cyclops	1	Cyclops
A. estrophiolata	1	Ironwood
A. farnesiana	2	Cassie Flower
A. holosericea	1	Umbrella Mulga
A. latzii	1	
A. ligulata	1	Umbrella Bush
A. linarioides	1	
A. mangium	1	
A. monticola	1	Cajaput Tree
Acacia nilotica	3	Egyptian Thorn
A. salicina	1	Cooba
A. senegal	4	Gum Arabic
A. seyal	1	Talh
A. tenuissima	1	
A. tortilis	3	Umbrella Thorn
A. tumida	1	
A. validinervia	1	
A. victoriae	2	Elegant Acacia
Adansonia digitata	1	Baobab
Amaranthus cruentus	1	Grain Amaranth
A. hypochondriacus	1	Grain Amaranth
Amelanchier utahensis	1	Serviceberrry
Anogeissus leiocarpus	1	
Argania spinosa	1	Argan Tree
Atriplex barclayana	1	
A. canescens	1	Four-Wing Saltbush
A. cinerea	1	
A. halimus	1	
A. leucoclada	1	
A. linearis	1	
A. nummularia	1	Old-Man Saltbush
Balanites aegyptiaca	1	Desert Date
Caesalpinia gilliesii	1	Yellow Bird of Paradise
Calliandra calothyrsus	1	
Carnegiea gigantea	1	Saguro

Cassia artemisioides	2	Silver Cassia
C. eremophilia	1	
C. italica	1	
C. sturtii	1	
C. wislizenii	1	Arizona Senna
Causarira decaisneana	1	
Centrosema sp.	1	Centro
C. brasilianum	1	
C. pascuorum	1	
Cercidium floridum	1	Blue Paloverde
Chilopsis linearis	1	Desert Willow
Conocarpus lancifolius	1	Damas
Cordeauxia edulis	2	Ye'eb
Cowania stansburiana	1	Cliffrose
Cretonia siliqua	1	Carob
Dasylirion wheeleri	2	Wheeler Sotol
Desmanthes virgatus	1	
Dodonea angustissima	1	
D. viscosa	2	Switchsorrel
Echinocereus Boyce-thompsonii	1	Hedgehog
Encelia farinosa	1	Brittlebush
Eucalyptus brockwayi	1	Dundas Mahogany
E. camaldulensis	3	River Red Gum
Eucalyptus intertexta	1	Inland Red Box
E. melanophloia	1	Silver-Leaved Ironbark
E. microtheca	2	Flooded Box
E. occidentalis	1	Flat-Topped Yate
E. oleosa var. oleosa	1	Narrow-Leaved Giant Mallee
E. terminalis	1	
E. tessellaris	1	Carbeen
E. torquata	1	Coral-Flowered Gum
Ferocactus wislizenii	1	Fish Hook Barrel
Fraxinus anomala	1	Singleleaf Ash
Geoffroea decorticans	2	
Grayia brandegei	1	Spineless Hopsage
Hyphaena thebaica	1	Doum Palm
Idria columnaris	1	Bojum Tree
Larrea tridentata	1	Creosote-Bush
Leucaena leucocephala	5	Leucaena
Leucaena retusa	1	Golden-Ball Lead Tree
Linum lewisii	1	Rocky Mountain Flax
Lysiloma microphylla	1	Little Leaf Lysiloma
Macroptilium atropurpureum	2	Siratro
M. martii	2	
Melaleuca lasiandra	1	
Melia azedarach	2	Indian Lilac
Mitragyna inermis	1	
M. inermis	1	
Olynea tesota	1	Desert Ironwood
Orthocarpus pururasiens	1	Owl Clover
Pachycereus pecten-arboriginum	1	Indian Comb

Panicum sonorum	1	Panic Grass
Parkinsonia aculeata	4	Horse-Bean Tree
Penstemon parryi	1	Desert Penstemon
Phaseolus acutifolius	2	Tepary Bean
P. coccineus	1	Scarlet-Runner Bean
P. filiformis	1	
Pittosporum phillyraeoides	1	
Proboscidea sp.	1	Devil's Claw
Prosopis hybrid PC 004	1	
Prosopis hybrid PC 005	1	
P. africana	2	
P. alba	3	Algarrobo Blanco
P. chilensis	2	Algarrobo
P. glandulosa	2	Honey Mesquite
P. glandulosa var. glandulosa	2	Honey Mesquite
P. glandulosa var. torreyana	1	Western Honey Mesquite
P. juliflora	3	Mesquite
P. juliflora var. torreyana	1	Western Honey Mesquite
Prosopis nigra	1	
P. pallida	1	Algarrobo
P. tamarugo	1	Tamarugo
P. velutina	8	Velvet Mesquite
Psophocarpus tetragonolobus	2	Winged Bean
Purshia glandulosa	1	Desert Bitterbush
Salvia greggii	1	Autumn Sage
Schinus molle	1	Pepper Tree
Sesbania grandiflora	1	Agati
Simmondsia chinensis	1	Jojoba
Stylosanthes guianensis	1	Stylo
S. hamata	1	Caribbean Stylo
S. scabra	3	Shrubby Stylo
S. sympodialis	1	
S. viscosa	1	
Tarchonanthus camphoratus	1	Camphor Bush
Tylosema esculentum	1	Morama Bean
Yucca elata	1	Soap Tree
Zea mays	2	Pima-Papago 60-day Maize
Zizyphus mauritania	1	Indian Jujube

APPENDIX F

May 6, 1983

MEMORANDUM

TO: Cooperating Researchers

FROM: Carol Corillon and Jeffrey Gritzner, National Research Council

SUBJECT: Seed Available for Trial Plantings

Enclosed is the fourth revision of our listing of seed available for trial plantings. Additions to the previous lists are indicated with asterisks.

Seed for the species listed is available in trial quantities to individuals and institutions actively engaged in systematic research. It has been selected by scientists familiar with the Sahel or with analogous drylands elsewhere. The provision of this seed is an element of the NRC's integrated program to increase the biological productivity of the Sahel. The program is supported by AID grant AFR-0929-G-SS-1104-00.

All seed shipments will be accompanied by basic reporting forms to be completed by the recipients. These records will allow the NRC, the Sahel Institute, and other interested parties to evaluate the performance of the species involved.

Requests for seeds should be directed to us at the following address:

Board on Science and Technology for
International Development (JH 223)
National Research Council
2101 Constitution Avenue
Washington, D. C. 20418

The Office of International Affairs of the National Research Council serves the international interests of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine

SEED AVAILABLE

	Species	Common Name	Supplier	Number	Origin	Comments
Crops						
1.	*Amaranthus cruentus*	Grain Amaranth	Rodale Research Center	R104	Mexico	Mexican grain-type amaranth. High-protein grain, protein-rich leaves, fast growing, day-length neutral.
2.	*A. hypochondriacus*	Grain Amaranth	Rodale Research Center	R103	Mexico	Mercado grain-type amaranth. High-protein grain, protein-rich leaves, fast growing.
3.	*Panicum sonorum*	Panic Grass	Meals for Millions		Sonora, Mexico	Forage and edible seed.
4.	*Phaseolus acutifolius*	Tepary Bean	Meals for Millions		Sells, Arizona	Drought-tolerant, forage, edible seed.
5.	*P. acutifolius*	Tepary Bean	Meals for Millions		Coolidge, Arizona	Same as above.
6.	*P. coccineus*	Scarlet-Runner Bean	Native Seeds/SEARCH		Panalachic, Chihuahua, Mexico	Edible seed, pods, and roots.
7.	*Psophocarpus tetragonolobus*	Winged Bean	University of Florida	Tpt-1	Southeast Asia	Edible seeds, pods, leaves, and roots, edible seed oil, livestock feed, relatively high water requirements.
8.	*P. tetragonolobus*	Winged Bean	Asia Foundation Winged Bean Program	F-452		Same as above.
9.	*Tylosema esculentum*	Morama Bean	Southwest Texas State University		Kalahari Desert	Edible tuber and seeds, oil, browse, drought tolerant.
10.	*Zea mays*	60-Day Maize	University of Florida		Southern Arizona	Grain and livestock feed.
11.	*Z. mays*	60-Day Maize	Meals for Millions		Parker, Arizona	Grain and livestock feed.

*New Accessions

Trees, Scrubs, and Pasture

*12.	Acacia adsurgens	Mulga	CSIRO, Australia	13738	Northern Territory, Australia	Supplementary fodder, durable timber, fencing, fuel.
13.	A. albida	Apple-Ring Acacia	ISRA/CNRF, Senegal	82/598	Nayobe, Senegal	Comes into leaf at the end of the rainy season and remains green during the dry season. Soil conservation, livestock feed, tannin, easily carved wood.
14.	A. aneura	Mulga	CSIRO, Australia	12791	New South Wales, Australia	Emergency browse, durable timber, fuel.
*15.	A. cambagei	Gidgee	CSIRO, Australia	13487	Queensland, Australia	Durable timber, fuel, fence posts.
*16.	A. coriacea	Wirewood	CSIRO, Australia	13768	Northern Territory, Australia	Browse, ground cover, fencing, fuel.
*17.	A. cowleana		CSIRO, Australia	13774	Northern Territory, Australia	Browse, fuel, shade, shelter, durable timber.
*18.	A. cyclops					Shipment being processed.
*19.	A. estrophiolata	Ironwood	CSIRO, Australia	13799	Northern Territory, Australia	Browse, fuel, shade, shelter, durable timber.
*20.	A. holosericea	Umbrella Mulga	CSIRO, Australia	13771	Northern Territory, Australia	Fuel, ground cover.
*21.	A. latzii		CSIRO, Australia	13780	Northern Territory,	Fuel, additional information on request.
22.	A. linarioides		CSIRO, Australia	11506	Western Australia	Soil conservation.
*23.	A. monticola	Cajaput Tree	CSIRO, Australia	13773	Northern Territory, Australia	Fuel, additional information on request.

24.	Acacia nilotica subsp. adstringens		ISRA/CNRF,	81/443	Thiarene, Senegal	Fuel, construction, fodder tannin, gum
25.	A. nilotica subsp. tomentosa	Egyptian Thorn	ISRA/CNRF, Senegal	82/597	Nayobe, Senegal	Fuel, living fences and wind-breaks, fodder, tannin, gum.
26.	A. salicina	Cooba	CSIRO, Australia	13379	Western Australia	Fuel, soil conservation.
*27.	A. senegal	Gum Arabic	ISRA/CNRF, Senegal	82/594	Northern Ferlo, Senegal	Fuel, construction, gum arabic, fodder, soil conservation, edible seed.
*28.	A. senegal					Shipment being processed.
*29.	A. seyal					Shipment being processed.
*30.	A. tenuissima		CSIRO, Australia	13800	Northern Territory, Australia	Fuel, additional information on request.
*31.	A. tortilis					Shipment being processed.
32.	A. tortilis subsp. raddiana	Umbrella Thorn	ISRA/CNRF, Senegal	82/599	Niomre, Senegal	Fuel, construction, fodder, sand control.
*33.	A. tortilis subsp. raddiana					Shipment being processed.
*34.	A. validinervia		CSIRO, Australia	13797	Northern Territory, Australia	Fuel, additional information on request.
*35.	A. victoriae	Elegant Acacia	CSIRO, Australia	13271	Queensland, Australia	Shelterbelts, browse, fuel.
*36.	A. victoriae					Shipment being processed.
37.	Adansonia digitata	Baobab	ISRA/CNRF, Senegal	82/603	Bandia, Senegal	Food, bark used to make mats and paper.
38.	Anogeissus leiocarpus		ISRA/CNRF, Senegal	82/571	Boulel, Senegal	Fence posts, construction and wood-working, ashes, yield potash.

*39.	Atriplex barclayana					Shipment being processed.
40.	A. canescens	Four-Wing Saltbush	Texas Tech University		Western Texas	Browse, ground cover.
*41.	A. cinerea					Shipment being processed.
*42.	A. halimus					Shipment being processed.
*43.	A. leucoclada					Shipment being processed.
*44.	A. linearis					Shipment being processed.
45.	A. nummularia	Old-man Saltbush	Western Australia Dept. of Agriculture	ACC WA-/1981	Western Australia	Browse, ground cover.
46.	Balanites aegyptiaca	Desert Date	ISRA/CNRF, Senegal	82/602	Louga, Senegal	Construction, edible fruit, browse, emulsion from the fruit is lethal to the snails that are intermediary hosts of schistosomiasis and to the water flea that carries the Guinea-worm disease, and is used to poison fish.
*47.	Cassia artemisioides					Shipment being processed.
*48.	C. eremophilia					Shipment being processed.
*49.	C. italica					Shipment being processed.
*50.	C. sturtii					Shipment being processed.
*51	Causarina decaisnena					Shipment being processed.

52.	Centrosema pascuorum		CSIRO, Australia	55697	Petrolina, Brazil	Forage.
*53.	Ceratonia siliqua					Shipment being processed.
54.	Conocarpus lancifolius	Damas	Baobab Farm, Kenya		Mombasa, Kenya	Construction, charcoal, fodder.
*55.	Dodonea angustissima		CSIRO, Australia	13753	Northern Territory, Australia	Fuel, additional information on request.
*56.	D. viscosa					Shipment being processed.
57.	Eucalyptus brockwayi	Dundas Mahogany	CSIRO, Australia	12266	Western Australia	Sawlogs, posts, firewood.
58.	E. camaldulensis	River Red Gum	CSIRO, Australia	12184	Northern Territory, Australia	Coppices well, posts, poles, piles, fuel, honey production.
59.	E. camaldulensis	River Red Gum	CSIRO, Australia	12346	Western Australia	Same as above.
60.	E. camaldulensis	River Red Gum	CSIRO, Australia	13476	Queensland, Australia	Same as above.
61.	E. intertexta	Inland Red Box	CSIRO, Australia	11736	New South Wales, Australia	Fuel, shelterbelts.
62.	E. melanophloia	Silver-Leaved Ironbark	CSIRO, Australia	13158	Queensland, Australia	Fuel, honey production.
63.	E. microtheca	Flooded Box	CSIRO, Australia	12846	Queensland, Australia	Fuel, poles and posts, conservation.
64.	E. microtheca	Flooded Box	CSIRO, Australia	13360	Western Australia	Same as above.
65.	E. occidentalis	Flat-Topped Yate	CSIRO, Australia	9806	Western Australia	Fuelwood, timber, shade.
66.	E. oleosa var. oleosa	Narrow-Leaved Giant Mallee	CSIRO, Australia	12310	South Australia	Construction, fuel, essential oil, honey.
67.	E. terminalia		CSIRO, Australia	11966	Queensland, Australia	Fuelwood, honey.

68.	Eucalyptus tessellaris	Carbeen	CSIRO, Australia	12967	Queensland, Australia	Fuelwood, honey production.
69.	E. torquata	Coral-Flowered Gum	CSIRO, Australia	10106	Western Australia	Ornamental plantings, honey production.
70.	Geoffroea decorticans		SACOR, Chile		Chilean coastal desert	Multiple use.
*71.	Hyphaena thebaica					Shipment being processed.
72.	Leucaena leucocephala	Leucaena	University of Hawaii	K8	Zacatecas, Mexico	Fuelwood, forage, construction, soil improvement.
73.	L. leucocephala	Leucaena	University of Hawaii	K30	Merida, Mexico	Fuelwood, forage, soil conservation.
74.	L. leucocephala	Leucaena	University of Hawaii	K67	Santa Cruz Porillo, El Salvador	Same as above.
75.	L. leucocephala	Leucaena	University of Hawaii	K500	Australia	"Cunningham" forage cultivar.
76.	Macroptilium atropurpureum	Siratro	CSIRO, Australia	Siratro		Forage.
*77.	Melaleuca lasiandra		CSIRO, Australia	13752	Northern Territory, Australia	Fuel, additional information on request.
78.	Mitragyna inermis		ISRA/CNRF, Senegal	82/604	Bandia, Senegal	Firewood, medicine, fish baskets.
*79.	Parkinsonia aculeata	Horse-Bean Tree	ISRA/CNRF, Senegal	83/771	Bandia, Senegal	Fuel, erosion control, fodder.
*80.	Pittosporum sp.					Shipment being processed.
81.	Prosopis africana		ISRA/CNRF, Senegal	106	Keur-Mactar, Senegal	Charcoal, tannin, construction.
*82.	P. africana		ISRA/CNRF, Senegal	82/672	Bayottes Classified Forest, Casamance, Senegal	Same as above.

83.	Prosopis alba	Algarrobo Blanco	Texas A&I University	0166	Argentina	Fuel, timber, fodder, food, amenity planting.
84.	P. alba	Algarrobo Blanco	Texas A&I University	0388	Argentina	Same as above.
*85.	P. alba	Algarrobo Blanco	University of California at Riverside	PC 062	Mexico	Same as above.
*86.	P. chilensis	Algarrobo	U.S. Department of Agriculture		Chile	Fuel, forage, durable wood, ornamental.
*87.	P. glandulosa var. glandulosa	Honey Mesquite	University of California at Riverside	PC 032	Santa Ana, Mexico	Browse, food for human consumption, fuel, posts, honey production.
88.	P. juliflora	Mesquite	ISRA/CNRF, Senegal	79/194	Saint-Louis, Senegal	Fuelwood, construction, fodder, food for human consumption, gum, honey.
*89.	P. julifora	Mesquite	ISRA/CNRF, Senegal	81/546	Louga, Senegal	Same as above.
*90.	P. nigra					Shipment being processed.
*91.	P. pallida					Shipment being processed.
*92.	P. tamarugo	Tamarugo	U. S. Department of Agriculture		Chile	Fuel, durable wood, forage, highly salt tolerant.
93.	P. velutina	Velvet Mesquite	Texas A&I University	0457	Kingsville, Texas	Browse, food for human consumption, fuel, posts, honey production.
*94.	P. velutina	Velvet Mesquite	University of California at Riverside	PC 035	Arizona	Same as above.
*95.	Schinus molle					Shipment being processed.
96.	Simmondsia chinensis	Jojoba	University of Arizona		Southern Arizona	Liquid wax, browse, salt tolerant, drought tolerant.

97.	Stylosanthes hamata	Caribbean stylo	CSIRO, Australia	Verano	Coastal South America	Forage.
98.	S. scabra	Shrubby Stylo	CSIRO, Australia	Q10042	Bahia, Brazil	Forage.
99.	S. scabra	Shrubby Stylo	CSIRO, Australia	Fitzroy		Forage.
100.	S. scabra	Shrubby Stylo	CSIRO, Australia	Seca		Forage.
101.	Tarchonenthus camphoratus	Camphor Bush	Bolus Herbarium University of Capetown		Bloemfontein, South Africa	Fuelwood, fodder, windbreaks, termite-resistant wood, medicinal uses.
*102	Zizyphus mauritiana					Shipment being processed.

APPENDIX G

REPORTING FORM FOR SPECIES TRIALS

Accession

Date Sent _____
month/year

Recipient:

A. Was the accession planted? yes ____ no ____. If so, continue to the next section. If not, please indicate reason (for example, seed damaged, species not of interest, seed given to someone else):

B. Planting Information and Performance

1. Date of planting _____.

2. Method of planting (check one): direct seeding ____, seedlings ____.
   If seedling, open-rooted ____, other (specify)_____.

3. Seedling performance: failed ____, poor ____, good ____, excellent ____.

4. Was seedling inoculated? yes ____ no ____. If so, inoculum used _____.

C. Site Description

1. Precipitation:

   Long-term average: _____mm.

   Rainfall when planted: below normal ____, normal ____, above normal _____.

   Rainfall distribution: normal ____, abnormal ____.

2. Topography: flat ____, hilly ____. If hilly, slope was: steep ____, medium ____, gentle ____.

3. Soil:

   Classification (if known):_____.

   Depth: deep ____, intermediate ____, shallow ____.

   Eroded: yes ____, no ____.

   Texture (circle one or combination): clay silt loam sand

   pH (check one or more): acid ____, neutral ____, alkaline ____, (saline ____).

4. Natural vegetation of trial area _____ .

D. Comments (for example: unforeseen complications) and recommendations:

APPENDIX H

REPRESENTATIVE LISTING OF ACOS SCIENTIFIC NETWORKING CONTACTS

Academy of Educational Development - Washington, D. C.
African-American Institute, The - Washington, D. C.
AFRICARE
Agricultural University, - Wageningen, The Netherlands
Agriculture Canada
American Association for the Advancement of Science (AAAS)
American Friends Service Committee (AFSC)
American University
Appropriate Technology International (ATI) - Washington, D. C.
Arizona Sonora Desert Museum - Tucson, Arizona
Arizona State University
Arizona, University of
Asociacion Latino-Americana de Rhizobiologos
Australian Conservation Foundation
Australian Development Assistance Bureau (ADAB)
Australia, Western Australia Department of Agriculture

Baobab Farm - Kenya
B.A.T. Kenya Limited - Meru, Kenya
Ben-Gurion University of the Negev - Israel
Botswana, Ministry of Mineral Resources and Water Affairs
Brazil, Institute of Forestry Development
Brazilian Corporation for Agricultural Research (EMBRAPA)
British Volunteer Program - Bamako, Mali
Butler University, Holcomb Research Institute

California Institute of Technology
California, University of at Berkeley
California, University of at Davis
California, University of at Riverside
California, University of at San Diego
Cape Town, University of - South Africa
Cape Verde, Center for Agrarian Studies, Ministry of Rural Development
CARE
Catholic Relief Services
Center for Disease Control (CDC) - Atlanta, Georgia
Centre Regional Africain de Technologie (CRAT) - Dakar, Senegal
Chad Basin Development Authority - Nigeria
Chad, Forest Service - N'Djamena
Chemical and Biological Research Institute - Ottawa, Canada
Chicago, University of
Chile, Pampa del Tamarugal Program - Santiago
China, Lanzhou Institute of Desert Research - People's Republic of China
Cincinnati, University of
Clark University
Club du Sahel Secretariat - Paris
Colorado State University

Colorado, University of Institute of Behavioral Science
Commonwealth Forestry Institute - Oxford, England
Commonwealth Scientific and Industrial Research Organization (CSIRO)
Division of Forest Research - Australia
CSIRO/Division of Tropical Crops and Pastures - Australia
Connecticut Agricultural Experiment Station
Coordination in Development (CODEL)
Cornell University
Czechoslovakian Academy of Sciences

Dakar, University of - Senegal
Dar-es-Salaam, University of
Desert Botanical Garden - Phoenix, Arizona
Desert Research Institute - Cairo, Egypt
Desert Research Project - Biosearch Trust, Cambridge, England
Duke University

Earth Satellite Corporation
East African Herbarium
East African Microbiological Resources Centre (MIRCEN)
Environment Training Programme (ENDA) - Dakar, Senegal
Export Nurseries - Maldegen, Belgium

Family Health Care, Inc.
Florida, University of
Foundation for Microbiology - New York City
France, Office de la Recherche Scientifique et Technique Outre-Mer
(ORSTOM)
France, Tropical Agronomic Research Institute (IRAT)
French Scientific Mission - Washington, D. C.

Gabon, Ministry of Planning and Development
Gambian-Germany Forestry Project - Banjul, The Gambia
General Delegation for Scientific and Technological Research
(DGRST)-France
Georgia, University of
German Agency for Technical Cooperation (GTZ)
German Forestry Mission - Eschborn, West Germany
Ghana, Northern Region Rural Integrated Program
Greenhills Center and Experimental Station - Cedar Hill, Texas
Gum Arabic Company - Khartoum, Sudan

Hawaii, University of, NifTAL
Howard University

Idaho, University of
Illinois, University of
India, Forest Research Institute and Colleges - Dehra Dun
India, National Botanical Research Institute
Industrial Services International - Brandenton, Florida
Innsbruck, University of - Austria
Integrated Resource Information Services (IRIS) International -
Landover, Maryland

Institute for Development Anthropology - Binghamton, New York
Institute for World Forestry - Hamburg, West Germany
Instituto Nacional de Investigaciones sobre Recursos Bioticos (INIREB)-Mexico
International Agricultural Development Service (IADS) - New York City
International Bank for Reconstruction and Development (IBRD)
International Council for Research in Agroforestry (ICRAF)
International Crops Research Institute for the Semi-arid Tropics (ICRISAT)
International Development Research Centre (IDRC)
International Forest Service Consultancy - Midlothian, United Kingdom
International Foundation for Science (IFS) - Stockholm, Sweden
International Institute for Environment and Development
International Livestock Centre for Africa (ILCA)
International Maize and Wheat Improvement Center (CIMMYT) - Mexico
International Monetary Fund (IMF)
International Resources Development and Conservation Services - Boise, Idaho
International Science and Technology Institute - Washington, D. C.
International Technology Development Group - London
International Tree Crops Institute
International Union for Conservation of Nature and Natural Resources (IUCN)
Israel Forestry Association
Johns Hopkins University
Jojoba Plantation Partners - Santa Paula, California

Karolinski Institute - Stockholm, Sweden
Kenya, Ministry of Environment and Natural Resources - Nairobi
Kettering, Charles F., Research Laboratory - Yellow Springs, Ohio
King Faisal University - Saudi Arabia

Land Institute - Salina, Kansas
Languedoc, University of Science and Technology - Montpellier, France
Laval University - Canada
Liberian Geological Survey, Ministry of Lands, Mines and Energy
Lisbon, University of - Portugal
Louden Cattle Company - Branson, Colorado
Louisiana State University
Lund, University of - Sweden
Lutheran World Federation
Lyon, University of - France

Malawi, Department of Forestry
Mali, Forest Service
Maryland, University of
Massachusetts, University of
Mauritania, Agricultural Service
Mauritania, Embassy of - Washington, D. C.
Mauritania, National Agricultural School
Mauritania, Service for the Protection of Nature

Meals for Millions Foundation - Tucson, Arizona
Mennonite Central Committee
Mexico, Division of Forestry and Wildlife
Michigan State University
Michigan, University of
Minnesota, University of
Montana, University of
Montreal, University of - Canada

Nairobi, University of - Kenya
National Center for Atmospheric Research
National Defense Authority
National Land for People Foundtion - Fresno, California
National Museum of Natural History - France
National Science Foundation (NSF)
National University - Australia
Native Plants - Salt Lake City, Utah
Native Seeds/SEARCH - Tucson, Arizona
Nebraska, University of
New Mexico, University of
Nigeria, Federal Department of Forestry - Kanduna
Nigeria, Kano State Forestry Service
Nitragin Company, The
North American Plant Breeders
North Carolina State University
North Carolina, University of
Northwestern University
NUS Corporation - Denver, Colorado

Oak Ridge National Laboratory
Ohio Agricultural Research and Development Center - Wooster
Oklahoma State University
Oklahoma, University of
Oregon State University
Organization for Rehabilitation through Training (ORT)
OXFAM
Oxford, University of - England

Pakistan, National Agriculture Research Center (NARC) - Islamabad
Pasteur Institute
Pennsylvania, University of
Permanent Interstate Committee for Drought Control in the Sahel (CILSS)
Peter McLaughlin Associates (Camox, British Columbia)
Polish, Academy of Sciences, Institute of Geography and Spatial Organization
Porto Alegre (Brazil) MIRCEN
Purdue University

Remote Sensing Institute - South Dakota State University
Research Center for International Agrarian Development - West Germany
Rioja, Universidad Provincial de la - Argentina

Rockefeller Foundation
Rodale Research Center - Kutztown, Pennsylvania
Royal Botanic Gardens - Kew, England
Rural American - Washington, D. C.

Sahel Institute
Senegal, Secretariate of State for Scientific and Technical Resources (SERST)
Senegalese Forest Service
Senegalese Institute of Agricultural Research (ISRA)
Senegalese National Agricultural Research Center (ISRA/CNRA)
Senegalese National Forestry Research Center (CNRF)
Senegalese National Laboratory for Livestock and Veterinary Research (ISRA/LNERV)
Smithsonian Institution
Sociedad Agricola Corfo - Chile
Solar Energy Research Institute (SERI)
South Dakota State University
Southwestern Texas State University
Swiss Development Cooperation (DDA)

Tennessee Valley Authority
Texas A&I University
Texas A&M University
Texas Department of Health - Austin
Texas Tech University, International Center for Arid and Semi-arid Land Studies
Texas, University of
The Gambia, Forestry Department - Banjul
Toronto, University of - Canada
Tunisia, Ministry of Agriculture, Office of Hydrology

United Nations Development Programme (UNDP)
United Nations Educational, Scientific, and Cultural Organization, (UNESCO)
United Nations Environment Programme (UNEP)
United Nations Food and Agriculture Organization (FAO), Forestry Department
United Nations Sudano-Sahelian Office (UNSO)
United States Agency for International Development (AID)
United States, Congress of, Office of Technology Assessment
United States Department of Agriculture (USDA)
USDA - Forest Service
USDA - Fruit and Vegetable Chemistry Laboratory - Pasadena
USDA - Nitrogen Fixation and Soybean Genetic Laboratory - Beltsville, Maryland
United States Department of Commerce
United States Department of Interior
United States Office of Science and Technology Policy
United States Peace Corps
United States Soil Conservation Service

United States, Department of State
Utah State University, Institute for Land Rehabilitation

Virginia Polytechnic Institute

Washington University
Washington, University of
West African Development Bank
West African Microbiological Resources Center (MIRCEN)
World Bank, The (see IBRD)
World Health Organization (WHO)
World Resources Institute - Washington, D. C.
World Wildlife Fund (WWF)

Yale University

Zimbabwe, Agriculture and Rural Development Authority (ARDA) - Harare