RESEARCH STRATEGIES AND RESEARCH PRIORITIES

FOR THE CEREALS PROGRAMS, TEAMS AND NETWORKS OF ICRISAT

1989-1993

PEARL MILLET AND SORGHUM

ICRISAT CENTER

ICRISAT SAHELIAN CENTER

SADCC-ZIMBABWE

WASIP-MALI

WASIP-NIGERIA

EARCAL-KENYA

LASIP-MEXICO

ICRISAT

International Crops Research Institute for the Semi-Arid Tropics

Patancheru, Andhra Pradesh 502 324, India

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Mission Statement

The cereals programs, teams and networks (i) do strategic, adaptive and applied research on sorghum, pearl millet and finger millet to provide National Agricultural Research Systems (NARS) of countries in the Semi-Arid Tropics (SAT) with (a) screening and other breeding technologies, (b) breeding lines to facilitate development of cultivars, (c) seed and pollen parents for hybrid seed production, and (d) cultivars adapted to the various agro-ecosystems of the region, and (ii) assist in training of NARS scientists and technicians to increase their research capabilities.

Research Goals

Research is designed to improve (a) adaptation to temperature and drought stress, (b) resistance to diseases, insect pests, and the parasitic weed Striga, and (c) the grain yield potential and food, feed and forage quality of sorghum, pearl millet and finger millet in the various agro-ecosystems of the SAT, and (d) to broaden the germplasm base of sorghum, pearl millet, finger millet, foxtail millet, and other minor millets that are adapted to the SAT.

Strategy

The programs will do strategic, adaptive and applied research. ICRISAT Center (IC) will be largely responsible for strategic research and regional programs for adaptive and applied research. Responsibility for regionally important strategic research, however, will be assigned to regional programs. Research projects in which NARS have an advantage in expertise over IC will be conducted as cooperative projects with NARS or transferred to NARS. Research projects that have served their usefulness will be terminated.

Research will include breeding open pollinated cultivars as well as breeding seed and pollen parents, and maintainer lines for hybrid seed production. The value of topcross versus single cross hybrids in pearl millet will be investigated as a means of maintaining the yield advantages of a hybrid cultivar, and at the same time increase the stability of disease resistance and adaptability across a range of agro-ecosystems. Breeding lines will be shared with NARS, among regional programs, and between IC and regional programs.

The strategy in pearl millet and sorghum will be to breed for specific maturity dates for specific regions and agro-ecosystems. To ensure productivity under conditions of terminal heat and drought stress in all cultivars, a selection procedure involving yield potential, adaptation, and phenology will be followed. Studies have shown that in pearl millet the ratio of grain mass to total inflorescence mass (threshing percentage) measured in large populations under stress

provides a convenient selection criterion for resistance to terminal heat and drought stress.

In India emphasis will shift from breeding long- to medium-duration pearl millet for south central India to breeding short-duration cultivars for Rajasthan with its short growing season and unpredictable rainfall patterns.

Research on pearl millet at SADCC-Zimbabwe will shift from breeding for grain yield only, to include breeding for forage yield and quality. The forage potential of hybrids involving pearl millet and wild species of Pennisetum, and their derivatives will be investigated. SADCC-Zimbabwe will also breed seed parents, pollinators and restorer lines of sorghum, and increase variation in breeding lines of finger millet for use by NARS in southern Africa.

The use of pearl millet and sorghum as fodder is important also in West Africa and India. The pearl millet program at ISC will cooperate with ILCA to assure that cultivars released to farmers have acceptable fodder quality. The program at IC will develop cooperative projects with NARS to assure fodder quality in breeding lines and cultivars of pearl millet and sorghum released to NARS in Asia.

Breeding of rabi (post rainy season) sorghums, and breeding of sorghum for Striga resistance in India will be conducted as cooperative research projects with NARS. Research will emphasize the introduction of Striga resistance into advanced sorghum breeding lines and identification of agricultural practices that can help control this parasitic weed in farmers' fields. The sorghum cultivars ICSV 145 (SAR 1) resistant to S. asiatica in India, and Framida resistant to S. asiatica and S. hermonthica in Africa will be used as sources of resistance in breeding projects. Mechanisms of resistance, their molecular basis, and chemical control of Striga will be studied in cooperation with mentor institutes in the United Kingdom (UK) and the United States of America (USA). The rabi project will emphasize, resistance to terminal drought stress and lodging, and grain and fodder yield.

LASIP-Mexico will shift from breeding grain sorghum hybrids, to breeding food grain cultivars for use by small farmers on the intermediate highlands of Mesoamerica.

WASIP-Nigeria will breed hybrid sorghums adapted to the major sorghum growing regions of Nigeria and acceptable to the local brewing industry. WASIP-Mali will breed food grain sorghum cultivars for West Africa.

EARCAL-Kenya will concentrate on adapting sorghum breeding lines and cultivars bred at IC and WASIP for use by NARS in eastern Africa. Improving finger millet as a cereal for Uganda and Ethiopia will be added to the responsibilities of EARCAL.

Research emphasis in the program at IC on sorghum for the next five years will be to breed hybrids for the rainy season that are resistant to grain molds, and in cooperation with NARS will breed hybrids for

the postrainy season that do not lodge under conditions of terminal drought stress. Resistance to grain mold has been identified in landraces with acceptable grain qualities, and we are making progress in introducing resistance into breeding lines with high yield potential. Stalk rot (lodging) in sorghum is caused by species of several fungal genera. We select for delayed senescence (stay green) as a trait to avoid lodging.

Research emphasis in sorghum entomology will be on incorporation of multiple resistance traits into breeding lines. Resistance to stem borers is genetically complex and we will study the effects on yield of introducing the various resistance traits into advanced breeding lines. Acceptable resistance to shootfly has so far been identified only in species of Parasorghum. Some progress has been made with crossing Parasorghum to sorghum breeding lines. We will also use embryo rescue to produce hybrids and backcross derivatives as a means to facilitate transfer of resistance into grain sorghum. In pearl millet emphasis will be on identifying resistance to the earhead caterpillar and stem borer.

We will increase strategic and adaptive research on finger millet for cultivation in the SAT. Collection, evaluation and documentation of finger millet (Eleusine coracana), foxtail millet (Setaria italica), yellow foxtail (Setaria pumila), japanese millet (Echinochloa crusgalli), barnyard millet (Echinochloa colona), proso millet (Panicum miliaceum), little millet (Panicum sumatrense), kodo millet (Paspalum scrobiculatum) and Brachiaria ramosa will be continued by the genetic resources unit at IC.

Distribution of research responsibilities among programs, teams and networks allows for efficient use of resources. Regional programs and teams will adapt techniques developed at IC to regional needs, and networks will insure that regionally adapted technologies and regionally developed breeding lines and cultivars are successfully transferred to NARS.

The program at IC will serve as a regional program for Asia and will support the programs global responsibilities. The program will develop formal work plans for cooperative research with NARS in Burma, China, India, Pakistan and Thailand. We will request the Indian Council for Agricultural Research (ICAR) to place sorghum and millet scientists at IC to directly participate in improvement of these crops.

ICRISAT's research teams in Africa will provide research assistance, breeding material as well as hybrid parents and open-pollinated cultivars to NARS. A seed industry is essential for successful transfer of new cultivars from NARS to farmers fields. Training of NARS scientists in seed production technology will therefore become an essential component of the programs' regional activities. Another important component of the programs' activities in Africa will be the strengthening of NARS research capabilities through training, and assistance in developing research facilities.

As a long term strategy we plan to transfer resources from IC to Africa. During the next 5 years we will strengthen the research capability of EARCAL by improving research facilities on NARS experiment stations at Katumani and Kiboko in Kenya, of the WASIP-Mali team at Samanko, and of the WASIP-Nigeria team at Kadawa and Bagauda. We also plan to transfer IC research staff to regional programs in Africa, or place IC staff with NARS for periods of up to 2 years, where their expertise is needed.

ADMINISTRATIVE ORGANIZATION

The present system of having regional teams of scientists with centralized research facilities proved to be highly effective, and will continue.

Cereals research at ICRISAT is divided among the Cereals Program at ICRISAT Center (IC), the Pearl Millet Improvement Program at ICRISAT Sahelian Center (ISC), the Southern Africa Sorghum and Millet Improvement Program (SADCC-Zimbabwe), the West Africa Sorghum Improvement Program (WASIP) with research teams in Mali and Nigeria, the Latin America Sorghum Improvement Program (LASIP) in Mexico, and the Eastern Africa Regional Cereals and Legumes (EARCAL) program based in Kenya. Regional programs and teams have team leaders, and WASIP, EARCAL and the West Africa Pearl Millet Program (ISC) also have regional network coordinators to facilitate research cooperation among NARS and between NARS and ICRISAT. Regional networks have steering committees consisting of NARS scientists and administrators. Committees meet annually to advise ICRISAT on the research needs of participating NARS.

The program at IC is divided into research units for sorghum and pearl millet breeding, pathology, and physiology, cereal entomology and cell biology, and a Cooperative Cereals Research Network (CCRN) responsible for international sorghum trials and nurseries. Unit leaders of the program at IC, the leader of the LASIP team, and the coordinator of the EARCAL team report administratively to the Program Director at IC. The SADCC-Zimbabwe team reports to the Executive Director for southern Africa (SADCC/ICRISAT). The WASIP teams and the Pearl Millet Improvement Program at ISC report to the Executive Director for West Africa who is also Director of ISC.

Genetic resources and biochemistry are research units led by principal scientists who report administratively to the Deputy Director General at IC. These units serve both the cereals and legumes programs.

Distribution of Staff

The cereals program at IC in 1989 has 10 principal scientist positions including that of the program director, supported by 23 positions for nationally recruited scientists. We plan to reduce these numbers to 7 principal scientists, one international associate scientist and 18 nationally recruited staff by 1993. These reductions will be

achieved through transfer of key staff to regional programs in Africa, and by cancelling of selected positions as they become vacant. Principal scientists serve as research unit leaders. The sorghum breeding unit will then have positions for a principal and 3 nationally recruited scientists, and the millet breeding unit for a principal and 2 nationally recruited scientists. The sorghum and pearl millet pathology, and sorghum and pearl millet physiology units will be combined to form cereals pathology and physiology units each with positions for a principal and three nationally recruited scientists. The entomology unit will have positions for a principal and 2 nationally recruited scientists, the CCRN for a principal sorghum breeder and a nationally recruited scientist, and the cell biology unit for an international associate cell biologist and a nationally recruited cell biologist. Two nationally recruited scientists position will be assigned to each of biochemistry and genetic resources.

In EARCAL we presently have principal scientist positions for a sorghum breeder, a legumes agronomist, and a coordinator. The legumes program plans to add a legumes breeder to this team in 1992, and the cereals program plans to transfer a principal cereal pathologist in 1992 and a principal cereal physiologist in 1993 from IC to EARCAL.

In West Africa we have principal scientist positions in the pearl millet improvement program at ISC for two breeders, an entomologist, an agronomist and a pathologist, and a breeder stationed with WASIP-Mali. Two pearl millet germplasm botanists supported financially by the Institut francais de recherche scientifique pour le developpement en cooperation (ORSTOM, France) are associated with the ISC program. In Mali we have a sorghum breeder and an agronomist working directly with the Malian NARS. This bilateral project is expected to be concluded in 1990. The regional WASIP-Mali team has positions for a principal sorghum breeder, a principal pathologist, a team leader, a regional network coordinator and an economist. This team was strengthened in 1989 by the addition of a breeder, an agronomist and an entomologist from the Institut de recherches agronomiques tropicales at des cultures vivieres (IRAT, France). An agronomist from IRAT working on Striga has been assisting WASIP scientists since 1987. WASIP-Nigeria has positions for a principal sorghum breeder, a principal agronomist, a principal entomologist/team leader, and a principal physiologist. We propose to add a principal cereal pathologist position to this team in 1990.

The SADCC-Zimbabwe team includes positions for a principal sorghum breeder, a principal millet breeder, a principal pathologist, a principal entomologist, a principal agronomist, a principal food technologist, a soil scientist (IFDC) and a principal economist (IFPRI).

We have positions for a principal breeder and a principal agronomist/team leader assisted by a locally recruited breeder with LASIP in Mexico.

Postdoctoral research fellows are assigned to research units at IC by the training program as appropriate research projects and candidates

become available.

RESEARCH PRIORITIES

The sorghum and millet programs at ICRISAT Center (IC) were combined into a cereals program in 1986. Research projects were reviewed and redesigned to agree with ICRISAT's proposed 10-year plan developed in 1987. Research priorities are reviewed every three years. The present document presents recommendations of a global in-house review held at IC in February 1989, and of subsequent regional meetings of scientists of all ICRISAT's cereals programs, teams and networks. Research priorities are discussed separately for pearl millet and sorghum. Research projects are listed for each activity. Scientists with major responsibility for a project are listed. The research project is the basic unit of research at ICRISAT. In the cereals programs each scientist is responsible for at least one research project. Research progress is monitored through annual progress reports. Pearl millet projects are identified by M and sorghum projects by S. Projects at IC, EARCAL and LASIP are identified by IC, those at WASIP and ISC by IS, and those at SADCC by SD. The date following the title of a project indicates the date of expected completion or next review. Research priorities and regional research responsibilities are summarized for pearl millet in table 1 and for sorghum in table 2.

Pearl Millet

Research on pearl millet is conducted at IC, ISC, WASIP-Mali and SADCC-Zimbabwe.

Genetic Resources

Activities are germplasm collection, evaluation, documentation, conservation, distribution, and enhancement. Priority areas for collection of pearl millet are reviewed annually. Wild species and landraces are of special interest. Special emphasis at IC is on the formation of trait-specific gene pools as a means of providing potentially useful traits to plant breeders in the most desirable genetic backgrounds.

Research on the evaluation of wild and cultivated Pennisetum species is carried out at ISC under a collaborative project with ORSTOM. Priorities of this project are to understand the genetic mechanisms that cause partial genetic isolation of wild and cultivated gene pools, to identify the extent and effect of introgression from one to the other, and to identify traits in the wild species that are of potential value in the improvement of pearl millet.

GR-105(89)IC - Germplasm collection and maintenance of pearl millet and its wild relatives. S. Appa Rao and M.H. Mengesha. 1993.

GR-108(89)IC - Evaluation of pearl millet germplasm under different

environmental conditions in India and Africa. S. Appa Rao and M.H. Mengesha. 1993.

GR-118(89)IC - Pearl millet conversion and gene pool formation. S. Appa Rao and M.H. Mengesha. 1993.

GR-119(89)IC - Viability and genetic stability of cereal germplasm under different conditions of conservation. M.H. Mengesha and N. Kameswara Rao. 1993.

M-509(89)IS - Pearl millet germplasm evaluation. S.O. Okiror. 1993.

M-517(89)IS - Genetic structure of Pennisetum species. L. Marchais and S. Tostain. 1990.

M-520(89)IS - Evaluation of wild germplasm for pearl millet improvement. L. Marchais, S. Tostain and A. Ibrahim. 1992.

Physiology

Research in physiology supports the breeding projects. Research emphasizes (i) control of crop development by photoperiod and temperature, and the use of this information to test the consequences of differences in phenology; (ii) work on yield component interactions and their response to selection; (iii) studies on the basis for heterosis in topcross hybrids; and (iv) evaluation of simulation models as a tool in the breeding process.

M-110(89)IC - Evaluation of specific characters and hypotheses relating to yield and yield stability in pearl millet. F.R. Bidinger. 1993.

M-119(89)IC - Control of flowering by photoperiod and temperature in pearl millet and sorghum. G. Alagarswamy. 1993.

Physical Stress

Crop establishment is a problem of considerable importance in the Sudanian and Sahelian zones of West Africa, and parts of India and the SADCC region. At IC and ISC we screen breeding lines for resistance to temperature and drought stress, and determine the heritability of resistance and the progress possible in breeding for it. Research at ISC focuses on post-emergence seedling survival, and that at IC on emergence itself and on specific mechanisms of resistance to high temperature stress.

Field screening for resistance to terminal drought is a continuing activity at IC, ISC and SADCC. Research at IC and ISC concentrates on evaluation of breeding material, screening methodology and the heritability and mechanisms of resistance.

M-121(89)IC - Repeatability and applicability of pearl millet drought nursery results. V. Mahalakshmi. 1990.

M-122(89)IC - Identification and assessment of drought resistance in pearl millet. V. Mahalakshmi. 1993.

M-135(89)IC - Improvement of pearl millet for crop establishment. P. Soman, J.M. Peacock and L.K. Fussell. 1993.

M-519(89)IS - Evaluation of pearl millet for resistance to terminal drought in West Africa. L.K. Fussell and F.R. Bidinger. 1991.

ICAR-ICRISAT-PM-4(1990). Evaluation of pearl millet germplasm and breeding lines for adaptation to Western Rajasthan. E. Weltzien, J.R. Witcombe, V. Mahalakshmi and M.B.L. Saxena. 1993.

ICAR-ICRISAT-PM-6(1990). Evaluation of pearl millet germplasm and breeding lines for tolerance to heat stress and drought. V. Mahalakshmi, F.R. Bidinger, P. Soman and K.L. Vyas. 1993.

Disease Resistance

Downy mildew (Sclerospora graminicola) is the most important disease of pearl millet. Breeding material is being screened for resistance, and multilocational testing for resistance is being conducted on a continuing basis by IC, ISC and SADCC. Research at IC involves studies on (i) the nature of resistance; (ii) symptom expression in relation to inoculation, environment and genotype; (iii) anatomical and biochemical components of resistance; (iv) inheritance of resistance using pure lines of the host and pathogen, and (v) pathogen biology, genetics of virulence, oospore germination, and evolution of new pathotypes.

Rust (Puccinia penniseti) research is being conducted at IC on pathogen biology, development of reliable and efficient screening procedures, resistance identification, and inheritance of resistance. We also routinely screen breeding material for smut (Tolyposporium penicillariae) resistance at IC and ISC, and for resistance to false mildew (Beniowskia sphaeroidea) of pearl millet and blast (Pyricularia sp.) of finger millet at SADCC. We test ergot (Claviceps fusiformis) resistant lines bred at IC for use in SADCC, and at IC study the effect of host cytoplasm on ergot susceptibility, and on alkaloid content of sclerotia.

The cell biology unit assists in downy mildew research by developing complementary DNA probes for pathotype identification, using fluorescent antibody techniques for histopathological studies, and by producing haploids for genetic studies.

M-127(89)IC - Pearl millet rust: Biology, epidemiology and resistance identification. S.D. Singh. 1993.

M-134(89)IC - Collaborative pearl millet downy mildew research between ICRISAT Center and ICRISAT Sahelian Center. S.B. King and J. Werder. 1993.

M-137(89)IC - Panicle diseases of pearl millet: Biology and resistance

identification. R.P. Thakur and S.B. King. 1990.

M-141(89)IC - Biology of the pearl millet downy mildew pathogen. R.P. Thakur. 1993.

M-142(89)IC - Nature of resistance to downy mildew in pearl millet. S.D. Singh. 1993.

M-144(89)IC - Pearl millet disease evaluation and screening. S.B. King, S.D. Singh and R.P. Thakur. 1993.

M-514(89)IS - pearl millet downy mildew: Screening techniques and resistance identification. J. Werder, S.O. Okiror and K. Anand Kumar. 1993.

M-515(89)IS - Pearl millet smut and ergot: Screening techniques and resistance identification. J. Werder, S.O. Okiror and K. Anand Kumar. 1993.

M-803(89)SD - Identification of major millet diseases and screening for disease resistance in the SADCC region. W.A.J. de Milliano. 1993.

Striga Control

Because of the failure to identify genetic resistance to Striga in pearl millet, research on this parasitic weed at ISC focuses on cultural control methods. This involves studies on the effects of soil fertility, crop rotation, weeding, and methods of seedbed preparation on incidence of Striga.

M-516(89)IS - Striga hermonthica: Biology, screening and resistance identification in pearl millet. J. Werder. 1989.

Insect Resistance

Insect pests on pearl millet are severe only in West Africa where ICRISAT does research on the millet stem borer (Coniesta ignefusalis) the millet earhead caterpillar (Heliocheilus albipunctellus), and the scarabid beetle (Rhinyptia infuscata).

The biology of the stem borer is well understood and a field screening method for resistance has been developed. Emphasis is on screening germplasm to find sources of resistance, on obtaining quantitative data on the relationship of borer populations to crop damage and yield losses, and on methods of crop residue management to reduce populations of diapausing larvae.

The bioecology of the millet earhead caterpillar is poorly understood, and no reliable screening method for resistance is available. Research concentrates on artificial infestation using insect rearing, and on identifying inflorescence characteristics that might confer resistance to this pest. No information is available on the biology and economic importance of the scarabid beetle.

Research is being initiated at SADCC-Zimbabwe on the finger millet stem borer (Chilo partellus) on finger millet to identify sources of resistance. This pest can cause considerable damage to finger millet in southern and eastern Africa.

M-518(89)IS - Studies on infestation techniques and biology of Coniesta and Heliocheilus albipunctellus. M.J. Lukefahr. 1993.

M-521(89)IS - Estimating yield losses resulting from infestations by pearl millet insect pests. M.J. Lukefahr. 1993.

M-522(89)IS - Establishment of laboratory cultures of the pearl millet stem borer and earhead caterpillar. M.J. Lukefahr. 1993.

M-523(89)Is - Screening for resistance to pearl millet stem borer and earhead cater pillar. M.J. Lukefahr. 1993.

Variety Breeding

Open-pollinated pearl millet varieties of short, medium, and long duration are being bred at IC, ISC and WASIP-Mali by recombining progenies from the genetic diversification project or by population improvement. Recurrent selection is used in population breeding to improve yield potential, stand establishment, and resistance to drought, heat and downy mildew, and at ISC also to stem borer.

At SADCC-Zimbabwe, emphasis is on medium to short duration varieties for use throughout southern Africa, and on long duration varieties for Tanzania. Varieties are bred by recurrent selection in several composites, or selected out of breeding lines from the variety breeding project at IC. Variety breeding is being reduced at IC, since the demand for open-pollinated cultivars is limited in India. Research emphasis is on population improvement methodology.

M-102(89)IC - Population improvement and breeding of pearl millet varieties by recurrent selection. J.R. Witcombe. 1993.

M-136(89)IC - Genetic diversification of pearl millet. E. Weltzien and J.R. Witcombe. 1993.

M-502(89)IS - Diversification of pearl millet and use of genetic variability. S.O.Okiror and K. Anand Kumar. 1993.

M-503(89)IS - Population improvement for high yield and disease resistance in pearl millet. K. Anand Kumar, S.O. Okiror and J. Werder. 1993.

M-506(89)IS - Identification of parents, genetic diversification, and use in pearl millet variety breeding. S.N. Lohani. 1993.

M-507(89)IS - Breeding of full-season pearl millet varieties (120-150 days). S.N. Lohani and J. Werder. 1993.

M-801(89)SD - Improvement of pearl millet for grain yield and desirable agronomic traits. S.C. Gupta. 1993.

Hybrid Breeding

Breeding of pearl millet male-sterile lines for NARS has high priority at IC and ISC. The useful life of hybrids in India has historically been short because of changes in virulence of the downy mildew pathogen. Breeding efforts concentrate on the genetic diversification of male-sterile lines to provide broad based resistance to downy mildew. Research is being initiated on the usefulness of hybrid seed parents for use in 3-way hybrids, and of populations rather than inbreds as pollen parents. At ISC selection for downy mildew resistance in potential male-sterile and restorer lines is receiving special attention. At IC about 1000 single cross hybrids are made and evaluated for yield potential each year, with emphasis on early-maturing cultivars. At SADCC, a similar number of hybrids, mainly on IC male-sterile lines, are yield tested each year.

M-105(89)IC - Breeding of pearl millet pollinators. B.S. Talukdar. 1993.

M-106(89)IC - Breeding of pearl millet male sterile lines. K.N. Rai. 1993.

M-107(89)IC - Breeding of pearl millet hybrids. K.N. Rai, B.S. Talukdar and J.R. Witcombe. 1993.

M-504(89)IS - Breeding of pearl millet seed parents and hybrids. K. Anand Kumar. 1993.

Cultivar Testing

There is limited transferability of pearl millet cultivars from India to West Africa because of differences in latitude, different abiotic stresses, and the susceptibility of resistant Indian genotypes to the more agressive strains of the downy mildew pathogen in West Africa. Emphasis therefore is on testing within regions, rather than on international testing. IC and ISC organize regional trials and provide material to cooperating NARS for incorporation into their breeding programs.

There is good correspondence in adaptation between SADCC and IC for short to medium duration cultivars, and a potential correspondence between ISC and SADCC for long duration cultivars. The potential of variety exchange between SADCC and ISC for long duration material will be explored by CCRN through an exchange nursery. CCRN will also assume responsibility for assembling and maintaining data bases on climate of important millet-growing regions and trial locations in India and Africa.

M-101(89)IC - Production and distribution of pearl millet breeding material. J.R. Witcombe. 1993.

M-143(89)IC - Maintaining data bases on CCRN nursery environments. S.B. Chavan and C.M. Pattanayak. 1993.

M-146(89)IC - Cooperative pearl millet and finger millet trials and nurseries in eastern Africa. S.Z. Mukuru and V.Y. Guiragossian. 1993.

M-501(89)IS - Regional pearl millet testing and cooperation in West Africa. S.O. Okiror. 1993.

M-508(89)IS - Yield tests of pearl millet and exchange nurseries in the transition zone. S.N. Lohani and S.O. Okiror. 1993.

Grain Quality

Variation in grain quality of pearl millet is a major problem in West Africa, where ISC has collaborative research projects with NARS in Niger and Mali to study this problem. Research on grain quality and consumer preference of white and yellow grained millets is being initiated at IC to determine the desirability of such cultivars. Research on malting and food quality of pearl millet has been initiated at SADCC-Zimbabwe.

Fodder Quality

Research on the quality and use of pearl millet and of hybrids with P. purpureum as forages is being conducted at SADCC-Zimbabwe, where a laboratory for quality analyses and a project for feeding trials is being established.

Routine monitoring of advanced breeding lines for stover quality has been initiated by ISC through a collaborative agreement with ILCA. The feasibility of introducing the brown midrib gene into adapted grain varieties to improve stover quality is being investigated at IC.

M-805(89)SD - Breeding sorghum and millet for forages. S.C. Gupta and M. Osmanzai. 1993.

Crop Management

Agronomic research has high priority in West Africa where improvement in crop management is at least as important for sustainable production of pearl millet as is genetic improvement. Major emphasis is on the improvement and maintenance of soil fertility, development of soil management systems to improve water storage and availability, and development of productive cropping systems based on pearl millet. Screening for variety adaptation to low soil phosphorus levels has been started in cooperation with the Resource Management Program at ISC. Agronomic research on forage production systems is planned at SADCC-Zimbabwe.

M-512(89)IS - Evaluation and intensification of pearl millet production systems in the Sahelian zone. L.K. Fussell. 1989.

M-513(89)IS - Evaluation of intercropping systems based on pearl millet as the cereal. L.K. Fussell. 1989.

Impact Studies

Very little is known about farmer reaction to new pearl millet varieties, and of farmer preference for fodder or grain types. Surveys are planned at IC, ISC, WASIP and SADCC in collaboration with NARS to determine how cultivars can be made more readily acceptable to farmers. Rate of acceptance of new cultivars by seed companies, and the effectiveness of these companies in making seed available to farmers are also being studied by all cereals programs.

Cell Biology

The diversity of cytoplasms in Pennisetum is being studied using restriction fragment length polymorphism as genetic markers. Studies on the genetics of downy mildew resistance are planned using doubled haploids derived through anther culture.

M-140(89)IC - Characterization of cytoplasmic male sterility in pearl millet using RFLPs as genetic markers. S. Sivaramakrishnan and C.S. Busso. 1993.

M-147(M)IC - Genetic transformation and regeneration of pearl millet from protoplasts. F. Pinard and J.M.J. de Wet.

M-148(89)IC - Regeneration of functional haploid pearl millet plants from anther culture. S. Chandrapal and J.M.J. de Wet. 1993.

Training and Coordination

Programs at IC, ISC and SADCC place high priority on the sharing of research findings and methodology, breeding lines and cultivars with NARS scientists. These programs organize specialized training courses, regional and international workshops, field days and monitoring tours, and sponsor visits to IC for collaborators from NARS.

Annual meetings of millet scientists from IC, ISC and SADCC to improve communication and the sharing of technologies and breeding lines are planned to start in 1990. Coordination of cooperative pearl millet research by NARS in West Africa has been initiated through the program at ISC. This network is coordinated by one of the pearl millet breeders at ISC. The millet breeder at SADCC-Zimbabwe coordinates pearl millet research among NARS in southern Africa.

Finger Millet

Collection and maintenance of finger millet germplasm is the responsibility of the genetic resources unit at IC. SADCC-Zimbabwe and EARCAL do research on finger millet improvement for the high rainfall areas of Tanzania, Zambia, Malawi, Zimbabwe, Uganda and Kenya. Research involves assembling of local and exotic germplasm, regional testing of promising accessions, and crossing of selected genotypes to generate new breeding lines.

M-145(89)IC - Breeding high-yielding and blast resistant finger millet cultivars for eastern Africa. S.Z. Mukuru. 1993.

GR-104(89)IC - Assembly, maintenance and evaluation of minor millets germplasm. K.E. Prasada Rao. 1993.

M-802(89)SD - Breeding of finger millet for grain yield and food quality. S.C. Gupta. 1993.

Table 1. Research Activities for Pearl Millet at IC, ISC and SADCC. Symbols are C for continuing and N for new research; *** for highest priority, ** for intermediate priority, * for low priority; x for active research and - for no research.

Research Subject	Status	IC	ISC	SADCC
Genetic Resources				
Collection and maintenance		***	***	**
Collection	C	x	x	x
Conservation	C	x	-	-
Documentation	C	x	x	x
Genetic diversification		***	***	**
Exchange	C	x	x	x
Enhancement	C	x	x	x
Genetic research		**	***	-
Pennisetum biology	C	x	x	-
Physiology		***	**	*
Control of phenology	C	x	x	-
Yield determinants	C	x	-	x
Simulation modeling	N	x	-	-
Physical Stress				
Improved crop establishment		**	***	**
Screening	C	x	x	x
Research on mechanisms	C	x	x	x
Terminal drought resistance		***	***	**
Screening	C	x	x	x
Research on mechanisms	C	x	x	-
Disease Resistance				
Downy mildew		***	***	**
Screening	C	x	x	x
Biology	C	x	x	-
Nature of resistance	C	x	-	-
Rust		**	-	*
Screening	C	x	-	*
Biology	C	x	-	-
Nature of resistance	C	x	-	-

Research Subject	Status	IC	ISC	SADCC
Smut		**	**	**
Screening for resistance	C	x	x	x
Other diseases		*	*	**
Ergot biology	C	x	x	x
False mildew biology	C	-	-	x
Blast (finger millet) - Screening for resistance	N	-	-	x
Brown leaf spots	N	-	-	x
Striga		-	**	-
Cultural control	C	-	x	-
Insect Resistance				
Stem borer		-	***	-
Screening	C	-	x	-
Nature of resistance	N	-	x	-
Head caterpillar		-	***	-
Biology	C	-	x	-
Screening methodology	N	-	x	-
Stem borer (finger millet)		-	-	**
Screening	N	-	-	x
Variety Breeding		**	***	***
Abiotic stress resistance	C	x	x	x
Biotic stress resistance	C	x	x	x
Maturity and yield	C	x	x	x
Hybrid Breeding				
Male-steriles		***	**	*
Downy mildew resistance	C	x	x	x
Maturity classes	C	x	x	x
Cytoplasmic diversification	N	x	x	-
Pollinators		***	**	**
Inbreds	C	x	-	x
Topcross	N	x	x	-
Hybrids		***	**	**
Single-cross	C	x	x	x
Topcross	N	x	x	-
Specific adaptation	C	x	x	-

Research Subject	Status	IC	ISC	SADCC
Cultivar Testing		***	***	***
International trials	C	x	-	x
Regional trials	C	x	x	x
National trials	C	x	x	x
Trial data bases	N	x	x	x
Grain Quality		*	**	*
Screening	C	x	x	x
Industrial uses	N	-	-	x
Economics of quality	N	-	-	x
Forages		*	*	***
Breeding	N	-	-	x
Quality evaluation	N	x	x	x
Crop residues	N	x	x	x
Crop Management		-	***	***
Soil fertility maintenance	C	-	x	x
Soil moisture availability	C	-	x	x
Cropping systems	C	-	x	x
Impact Studies		**	-	**
Varietal acceptance	N	x	-	x
Food policy and marketing	N	x	-	x
Training and Coordination		***	***	***
Special training	C	x	x	x
Annual workshops/field days	C	x	x	x
Regional networks	C	-	x	x
Finger Millet		*	-	**
Collection	C	x	-	x
Breeding	C	-	-	x

Sorghum

Research on sorghum is conducted at IC, SADCC-Zimbabwe, WASIP-Mali, WASIP-Nigeria, EARCAL-Kenya and LASIP-Mexico.

Genetic Resources

Collection and conservation of sorghum germplasm are of strategic value in present and future sorghum improvement. The collections at IC are being characterized and documented to facilitate retrieval of information, and to identify useful genotypes. Multilocational evaluation of germplasm lines continues in collaboration with regional programs and networks, and with NARS. Photoperiod-sensitive germplasm lines with useful traits are being converted to day-neutral backgrounds to facilitate utilization of germplasm by breeders. Introgression of useful genes from wild sorghums into advanced breeding lines continues at IC.

GR-101(89)IC - Germplasm collection and maintenance of sorghum and its wild relatives. K.E. Prasada Rao and M.H. Mengesha. 1993.

GR-102(89)IC - Evaluation and documentation of the world collection of sorghum germplasm. K.E. Prasada Rao and M.H. Mengesha. 1993.

GR-103(89)IC - Sorghum conversion and introgression for germplasm enhancement and utilization. K.E. Prasada Rao. 1993.

Physiology

Studies on interaction of sorghum genotypes with temperature and photoperiod are conducted at IC and LASIP, and will be initiated at EARCAL. Collaborative research is being initiated with entomologists at IC to determine the effects of variations in temperature and photoperiod on shoot pests. Data on temperature and photoperiod interactions will be used to develop, in collaboration with RMP, sub-routines for sorghum growth models.

ICAR-ICRISAT-S-1 (1990). Screening sorghum breeding lines for photoperiod insensitivity and wide adaptability. B.V.S. Reddy, N. Seetharama and ICAR collaborators. 1993.

Physical Stress

Seedling vigour, and resistance to heat and drought stress in sorghum are priority areas of research at IC and WASIP-Nigeria. Research on heat shock proteins and the development of antibody based screening methods are being conducted in cooperation with institutes in the UK. Emphasis at LASIP is on screening and breeding of photoperiod-sensitive sorghums with resistance to low temperature for cultivation on the intermediate highlands of Central America.

Emphasis at IC is on screening and identifying mechanisms of resistance to terminal heat and drought stress in breeding lines for

postrainy season (rabi) cultivation, and at WASIP on selecting for cultivation in the Sahelian/Sudanian zone.

S-107(89)IC - Seed and seedling vigor in sorghum. P. Soman. 1993.

S-109(89)IC - Sorghum productivity under terminal drought stress. N. Seetharama. 1993.

S-140(89)IC - Resistance to thermal stress in sorghum and pearl millet seedlings. J.M. Peacock. 1993.

Disease Resistance

The incorporation of grain mold resistance (caused by several fungi) into advanced sorghum breeding lines is a major research objective of the program at IC. Improved cultivars mature at the end of the rainy season and are prone to infection. Resistance traits identified in landraces are being introduced into advanced breeding lines. Both white and red grained breeding lines resistant to grain mold are being developed. Research on the biology and biochemical mechanisms of resistance will continue.

Downy mildew (Peronosclerospora sorghi) and anthracnose (Colletotrichum sublineolum) are of destructive potential in all regions where sorghum is grown, and research at IC concentrates on nature of resistance and on pathogen variation. Screening to maintain resistance in advanced breeding lines will continue at IC, WASIP, SADCC, and LASIP.

Leaf blight (Setosphaeria turcica) is a serious disease in eastern and southern Africa and in Latin America, and long smut (Tolyposporium ehrenbergii) is of importance on sorghum in West and eastern Africa. EARCAL and SADCC will collaborate with IC in studies on the biology and epidemiology of leaf blight, and develop a screening technique to identify resistance in breeding lines. Research on biology and epidemiology of long smut, and breeding and screening for resistance will be conducted by WASIP and EARCAL in collaboration with IC.

Sooty stripe (Ramulispora sorghi) and grey leaf spot (Cercospora sorghi) are serious sorghum diseases in West Africa. Sooty stripe also occurs in southern Africa, and grey leaf spot in Latin America. Research by WASIP-Mali will focus on the biology and epidemiology of these diseases. Breeding and screening for resistance to sooty stripe will continue at WASIP-Mali and SADCC-Zimbabwe, and for grey leaf spot at WASIP and LASIP.

Ergot (Claviceps sorghi) on sorghum occurs in India, Thailand, eastern and southern Africa, and is likely to be important in hybrid seed production in Nigeria. In collaboration with NARS in Ethiopia and Rwanda we screen advanced breeding lines for resistance to ergot. Research at IC focuses on nature of resistance and the epidemiology of the disease.

Virus and bacterial diseases of sorghum are widespread across Africa,

Asia and America but rarely cause serious crop losses. Research at IC concentrates on characterization of the causal viruses and bacteria in India, and we collaborate with NARS in eastern and southern Africa on identification of viruses on sorghum in Africa.

S-110(89)IC - Biology of, and resistance to sorghum grain molds. R. Bandyopadhyay, L.K. Mughogho, D. Butler, R. Jambunathan and H.C. Sharma, 1993.

S-111(89)IC - Biology of, and resistance to sorghum anthracnose. Suresh Pande. 1993.

S-112(89)IC - Biology of, and resistance to sorghum downy mildew. L.K. Mughogho. 1993.

S-114(89)IC - Biology of, and resistance to sorghum ergot. R. Bandyopadhyay. 1991.

S-132(89)IC - Biology and control of sorghum long and covered smut, and ergot in eastern Africa. L.K. Mughogho, R. Bandyopadhyay, and V.Y. Quiragossian. 1993.

S-141(89)IC - Identification and characterization of sorghum and pearl millet viruses. L.K. Mughogho and D.V.R. Reddy. 1993.

S-142(89)IC - Diagnosis of bacterial diseases of sorghum. L.K. Mughogho. 1993.

S-505(89)IS - Screening sorghum for grain mold resistance in West Africa. M.D. Thomas. 1993.

S-506(89)IS - Biology of, and resistance to sorghum grey leaf spot. M.D. Thomas. 1993.

S-507(89)IS - Biology of, and resistance to sorghum sooty stripe. M.D. Thomas. 1993.

S-804(89)SD - Biology of, and resistance to sorghum leaf blight. W.A.J. de Milliano. 1993.

S-805(89)SD - Identification of sorghum diseases and screening for resistance in the SADCC region. W.A.J. de Milliano. 1993.

Striga Control

Striga hermonthica, S. asiatica, and S. forbesii are parasitic on sorghum. Resistant sorghum lines were identified, and the incorporation of resistance into advanced breeding populations continues at IC and WASIP. WASIP-Mali is intensifying research on cultural control as an adjunct to host plant resistance. Mechanisms of resistance, their inheritance, and the molecular basis of Striga seed germination and haustorium development are being studied in collaboration with institutes in the UK and USA. It is expected that these studies will lead to the development of effective and

inexpensive chemical control of these parasitic weeds.

S-147(89)IC - Control of Striga in sorghum fields. V.Y. Guiragossian, Y. Kebede and A. Sherif. 1993.

S-803(89)SD - Screening and evaluating sorghum and millets for resistance to Striga. A.T. Obilana and W.A.J. de Milliano. 1993.

ICAR-ICRISAT-S-2 (1990). Breeding and testing parental sorghum lines and cultivars for tolerance to Striga. P.K. Vaidya and ICAR collaborators. 1993.

Insect Pests

Research with sorghum at IC on host plant resistance continues, with emphasis on the identification of phenotypic traits that can be utilized in screening of breeding lines for resistance. Specifically at IC we endeavor to (i) increase the level of resistance to shoot fly (Atherigona soccata) through introgression from Parasorghum; (ii) increase the level of resistance to stem borer (Chilo partellus) in adapted genotypes through pedigree or recurrent selection; (iii) transfer midge (Contarinia sorghicola) resistance into advanced breeding lines and hybrid parents; and (iv) increase the level of resistance to head bugs (Calocoris angustatus and Eurystylus spp.) in breeding lines through introgression from resistant sources. Other research activities are the study of interaction between insect, host-plant and environment, the cartographic delineation of different pest species, and the assessment of crop losses caused by pests in different agro-ecological zones.

At IC we will intensify studies on the behavior of stem borer in relation to resistance factors, and will provide agronomically elite material with known levels of resistance to breeder at SADCC, WASIP and EARCAL. WASIP-Mali and WASIP Nigeria will undertake mass rearing of stem borers belonging to Busseola and Sesamia, and conduct screening for resistance to these insects in advanced breeding lines adapted to their regions. IC will continue to introduce midge resistance into advanced breeding populations for selection of open pollinated cultivars and hybrid parents, and supply improved breeding lines to WASIP where this pest is rated as high priority. LASIP will receive such breeding material for routine evaluation in Latin America.

Resistance to headbugs (Eurystylus spp.) is a high priority for research at WASIP-Mali. This team will improve and diversify the level of resistance to headbugs in elite breeding lines. IC will concentrate on Calocoris headbugs and provide support in screening methodology to regional programs. SADCC-Zimbabwe will serve both southern and eastern Africa as a center for research on storage insect pests, and will provide screening methodology to WASIP. At IC, routine screening of breeding lines will be undertaken to ensure resistance of improved varieties and hybrids to storage insects. The biology and cultural control of the armored cricket will be studied at SADCC-Zimbabwe.

S-133(89)IC - Identification and development of multiple insect resistance in sorghum. K.F. Nwanze. 1993.

S-134(89)IC - Bio-ecology and host-plant resistance to sorghum panicle pests. H.C. Sharma. 1993.

S-135(89)IC - Bio-ecology and host-plant resistance to sorghum shoot pests. S.L. Taneja. 1993.

Variety Breeding

Varietal improvement of sorghum involves pedigree and backcross methods to breed early (75-100 days), medium (100-125 days), and late (more than 125 day) maturing populations. Emphasis at IC is on early maturing pure lines with seedling vigor and resistance to shoot pests and grain mold, and medium maturing pure lines with resistance to grain mold, terminal drought stress and to stem borer and midge.

At WASIP-Mali, WASIP-Nigeria and SADCC, medium maturing lines with resistance to one or more diseases and pests (grain mold, anthracnose, sooty stripe, long smut, grey leaf spot, midge, head bug and stem borer), and to Striga are being bred. At SADCC emphasis is on breeding high yielding medium maturing lines and segregating populations for use by the NARS in southern Africa. Recurrent selection is being used to diversify these breeding populations.

High yielding early and medium maturing pure lines bred at IC are being evaluated in different agro-ecological zones by EARCAL, LASIP and WASIP. Improvement of late maturing pure lines is a major activity at LASIP and WASIP.

S-103(89)IC - Genetic diversification in sorghum. B.V.S. Reddy. 1993.

S-128(89)IC - Breeding cold tolerant sorghum for the highlands of Mexico and Central America. C.T. Hash and R. Clara. 1993.

S-130(89)IC - Breeding photoperiod-sensitive sorghums for intercropping systems in Latin America. C.T. Hash and R. Clara. 1993.

S-137(89)IC - Breeding early maturing, grainmold resistant sorghum lines. P.K. Vaidya and R. Bandyopadhyay. 1993.

S-138(89)IC - Breeding medium maturing sorghum lines. B.L. Agrawal. 1993.

S-148(89)IC - Breeding grain mold resistant sorghums. P.K. Vaidya, J. Stenhouse and R. Bandyopadhyay. 1993.

S-502(89)IS - Breeding medium maturing sorghum for intermediate rainfall regions of West Africa. K.V. Ramaiah. 1993.

S-503(89)IS - Breeding late maturing sorghum for high rainfall regions of West Africa. C. Luce. 1993.

S-504(89)IS - Breeding stable and high yielding early maturing sorghum for West Africa. 1993. D.S. Murty. 1993.

S-510(89)IS - Breeding sorghum varieties for the WASIP-Nigeria region. D.S. Murty, K.V. Ramaiah and C. Luce. 1993.
S-801(89)SD - Breeding sorghum with wide adaptation for the SADCC region. A.T. Obilana. 1993.

S-802(89)SD - Breeding sorghum populations for the SADCC region. A.T. Obilana. 1993.

Hybrid Breeding

Breeding improved sorghum seed parents and restorer lines for use by NARS are major activities at IC, and regional programs. At IC the main emphasis is on genetic diversification of seed parents and improving them for agronomic desirability in different maturity groups. Male-sterile lines are being bred for resistances to grain molds, Striga, shoot pests and midge. At WASIP-Nigeria, EARCAL, SADCC and LASIP, milo cytoplasm male-sterile lines bred at IC are being tested for regional adaptation, yield potential, and resistance to local diseases and pests. Backcross and pedigree breeding methods are being used to improve the male sterile and restorer lines.

S-104(89)IC - Breeding milo and non-milo cytoplasm male-sterile sorghum lines. B.V.S. Reddy. 1993.

S-129(89)IC - Breeding sorghum cultivars for the lowlands of Latin America. C.T. Hash and R. Clara. 1993.

S-139(89)IC - Sorghum hybrid production and testing. B.V.S. Reddy. 1993.

S-144(89)IC - Breeding high-yielding and adapted sorghum cultivars for eastern Africa. S.Z. Mukuru and V.Y. Guiragossian. 1993.

S-146(89)IC - Breeding early maturing sorghum cultivars adapted to dry lowland areas of eastern Africa. V.Y. Guiragossian and S.Z. Mukuru. 1993.

S-509(89)IS - Breeding sorghum hybrids for the WASIP-Mali region. K.V. Ramaiah, C. Luce and D.S. Murty. 1993.

ICAR-ICRISAT-S-3 (1990). Breeding of rabi based seed and pollen parents. B.V.S. Reddy, U.R. Murty and B.V.S. Rana. 1993.

ICAR-ICRISAT-S-4 (1990). Production of breeders seed. ICRISAT and ICAR scientists. 1993.

Cultivar Testing

ICRISAT collaborates through CCRN with NARS across Asia, Africa and Latin America in international sorghum trials and nurseries. CCRN also characterizes the edaphic and climatic environments of locations where trials are conducted, and assists NARS in on-farm testing of cultivars.

S-101(85)IC - International sorghum trials. C.M. Pattanayak. 1993.

S-136(89)IC - International sorghum nurseries. G. Alagarswamy. 1993.

S-145(89)IC - Cooperative sorghum trials and nurseries in eastern Africa. S.Z. Mukuru and V.Y. Guiragossian. 1993.

Cell Biology

Embryo rescue is being used to facilitate the transfer of genes responsible for shoot fly resistance from Parasorghum to elite sorghum breeding lines. Methods are being standardized to prepare probes for identification of viral diseases of sorghum. Methods for transformation of cereals by direct and indirect gene transfer is being developed. In cooperation with the University of Milan we are constructing a RFLP map of sorghum.

S-143(89)IC - Genetic transformation of sorghum and pearl millet. C.S. Busso and J.M.J. de Wet. 1993.

S-148(89)IC - Transfer of shoot fly resistance from Parasorghum into grain sorghum. J.M.J. de Wet, K.E. Prasada Rao and K.F. Nwanze. 1993.

ICRISAT-FRANCE-S-1(1990). Characterization of potyviruses occurring on sorghum in India and Africa. L.K. Mughogho, D.V.R. Reddy, M. Dollet. 1993.

Food and Industrial Uses

Grain quality and utilization of sorghum is being studied at IC, SADCC and WASIP-Nigeria. Research on malting and brewing quality is being conducted in cooperation with NARS and the local brewing industry by WASIP. Milling products, malted and fermented foods, and composite flour are being studied at SADCC-Zimbabwe, and industrial production of sorghum starch at IC. Other priority research areas are technology development and product diversification at SADCC-Zimbabwe, and the effect of head bug infestation on grain quality at WASIP-Mali.

S-106(89)IC - Evaluation of food and nutritional qualities of sorghum. V. Subramanian. 1993.

Forage and Crop Residues

The cereal programs breed sorghum for grain yield without neglecting forage potential. The forage quality of advanced breeding lines are

evaluated in collaboration with NARS in India and Africa.

Crop Management

Crop management is as vital a component in sorghum production strategies as is crop improvement. WASIP-Mali, WASIP-Nigeria, EARCAL and LASIP do research on cropping systems involving sorghum and legumes.

S-123(89)IC - Sorghum based cropping systems for Mexico, Central America and the Caribberan areas. C.L. Paul. 1993.

S-508(89)IS - Sorghum based cropping systems in Mali. S.V.R. Shetty. 1990.

Impact and Food Policy Studies

The economist at WASIP-Mali will study the effect of adoption of new cropping systems and new sorghum cultivars on farming systems and farm incomes in West Africa. Other areas of research are farmer decision making, land tenure patterns and land use as they affect cereal technology adoption and the expansion of sorghum utilization. SADCC-Zimbabwe conducts studies on policy, marketing and utilization of sorghum in the SADCC countries.

Training and Coordination

The needs and strengths of NARS differ considerably among countries. ICRISAT programs, teams and networks conduct field days, monitoring tours, regional and international workshops, short-courses and specialized training for NARS scientists and technicians. Meetings of regional network steering committees are held annually to provide ICRISAT network coordinators with policy guidelines. Training at IC emphasizes opportunities for scientists of NARS from Africa, Asia and Latin America to gain research and management experience, and for technical staff of NARS to gain experience in research methodology. SADCC-Zimbabwe provides short-term training at Matopos for NARS staff in southern Africa, WASIP conducts short-term training at Kano (Nigeria) and Samanko (Mali), EARCAL conducts discipline oriented training short-courses within the east African region, and LASIP uses the facilities at CIMMYT to train NARS scientists and technicians from Latin America.

Table 2. Research priorities for sorghum at IC, WASIP-Mali, WASIP-Nigeria, SADCC, EARCAL and LASIP. Symbols are C for continuing and N for new, *** for high priority, ** medium and * low priority, x for research and - for no activity.

Research area	Status	IC	WASIP-M	WASIP-N	SADCC	EARCAL	LASI
Genetic Resources							
Collection and Maintenance		***	-	-	**	-	-
Collection	C	x	-	-	x	-	-
Conservation	C	x	-	-	x	-	-
Documentation	C	x	-	-	x	-	-
Genetic diversification		***	**	**	**	*	*
Exchange	C	x	x	x	x	x	x
Enhancement	C	x	x	x	x	x	x
Physiology		**	*	**	*	*	-
Control of phenology	C	x	-	x	-	x	-
Yield determinants	C	x	-	x	x	-	-
Simulation modeling	N	x	-	x	-	-	-
Physical Stress							
Improved crop establishment		***	*	***	***	*	*
Screening	C	x	x	x	x	x	x
Breeding	N	x	-	x	-	-	-
Research on mechanisms	C	x	-	-	x	-	-
Thermal resistance	C	***	-	***	*	**	-
Screening	C	x	-	x	x	-	
Breeding	N	x	-	x	-	-	-
Research on mechanisms	N	x	-	x	-	-	
Cold resistance		-	-	-	**	**	**
Screening	C	-	-	-	x	x	x
Breeding	C	-	-	-	-	-	x
Research on mechanisms	N	x	-	-	-	-	-
Terminal drought resistance		***	**	***	**	*	*
Screening	C	x	x	x	x	x	x
Breeding	C	x	-	x	x	-	-
Research on mechanisms	C	x	-	x	-	-	-
Diseases Resistance							
Grain mold		***	**	**	**	**	*
Screening for resistance	C	x	x	x	x	x	x
Resistance breeding	C	x	x	x	-	-	-

Research area	Status	IC	NASIP-W	NASIP-N	SADCC	EARCAL	LASIP
Downy mildew		**	-	**	**	**	*
Resistance breeding	C	x	-	x	x	x	x
Pathogen variability	C	x	-	-	x	-	-
Nature of resistance	C	x	-	-	-	-	-
Anthracnose		**	*	*	**	*	-
Resistance breeding	C	x	x	x	x	x	x
Pathogen variability	C	x	-	-	-	-	-
Nature of resistance	N	x	-	-	-	-	-
Leaf blight		-	-	-	**	**	*
Resistance breeding	N	x	-	-	x	x	x
Biology/Epidemiology	N	-	-	-	x	x	-
Nature of resistance	N	-	-	-	x	-	-
Long smut		-	**	**	*	**	-
Resistance breeding	C	-	x	x	*	x	-
Biology/Epidemiology	N	-	x	x	-	-	-
Nature of resistance	N	-	-	x	-	-	-
Sooty stripe		-	**	**	**	-	-
Resistance breeding	N	-	x	x	x	-	-
Biology/Epidemiology	N	-	x	-	-	-	-
Nature of resistance	N	-	x	x	-	-	-
Grey leaf spot		-	**	**	**	-	*
Resistance breeding	N	-	x	x	x	-	x
Biology/Epidemiology	N	-	x	-	x	-	-
Ergot		***	-	**	**	**	-
Resistance breeding	C	x	-	x	x	x	-
Epidemiology	N	x	-	-	x	-	-
Nature of resistance	N	x	-	-	x	-	-
Virus diseases		**	-	-	**	**	**
Characterization	C	x	-	-	x	x	-
Bacterial diseases		**	*	*	**	*	*
Identification	N	x	-	-	x	-	-
Striga		*	***	*	***	*	-
Resistance breeding	N	x	x	x	x	x	-
Cultural control	N	-	x	-	x	-	-
Nature of resistance	C	x	x	-	x	-	-

Research area	Status	IC	WASIP-M	WASIP-N	SADCC	EARCAL	LASIP
Insect Pests							
Shoot fly		***	*	*	*	*	-
Identification of resistance	C	x	-	-	x	-	-
Resistance mechanisms	C	x	-	-	-	-	-
Insect/host interaction	N	x	-	-	-	-	-
Stem borer		***	***	***	***	***	**
Identification of resistance	C	x	x	x	x	x	x
Resistance mechanisms	C	x	-	-	x	-	-
Pest surveys	C	x	x	x	x	x	-
Insect rearing	C	x	x	x	x	-	-
Screening methodology	C	x	x	-	x	-	-
Insect/host interaction	N	x	-	-	-	-	-
Midge		***	*	***	**	*	**
Screening methodology	C	x	-	-	-	-	-
Resistance mechanisms	C	x	-	-	-	-	-
Breeding for resistance	C	x	-	x	-	x	x
Head bug		***	***	***	*	*	*
Screening methodology	C	x	x	-	-	-	-
Identification of resistance	C	x	x	x	-	-	-
Pest surveys	C	x	x	x	-	-	-
Insect biology	C	x	x	-	-	-	-
Resistance mechanisms	C	x	x	-	-	-	-
Storage pests		*	**	**	**	**	*
Identification of resistance	N	x	x	x	x	x	-
Screening methodology	N	-	-	-	x	-	-
Control	N	-	-	-	-	x	-
Armoured cricket		-	-	-	**	-	-
Identification of resistance	N	-	-	-	x	-	-
Pest surveys	N	-	-	-	x	-	-
Insect biology	C	-	-	-	x	-	-
Variety Breeding		***	***	**	***	***	***
Early maturity	N	x	-	x	x	x	x
Medium maturity	C	x	x	x	x	x	-
Late maturity	C	-	x	-	x	-	x
Population diversification	C	x	x	-	x	x	-
Hybrid breeding		***	**	***	**	**	**
Male Steriles	N	x	-	x	x	-	-
Pollinators	C	x	x	x	x	x	x

Research area	Status	IC	WASIP-W	WASIP-N	SADCC	EARCAL	LASIP
Cultivar Testing		***	***	***	***	***	***
International trials	C	x	x	x	x	x	x
Regional trials	C	x	x	x	x	x	x
On-farm	C	-	x	x	x	x	-
Trials data bases	N	x	x	x	x	x	x
Cell Biology		**	-	-	-	-	-
Embryo rescue	N	x	-	-	-	-	-
Molecular probes	N	x	-	-	-	-	-
Viral identification	N	x	-	-	-	-	-
RFLP's	N	x	-	-	-	-	-
Food and Industrial Uses		**	-	**	***	-	-
Malting and brewing quality	N	x	-	x	x	-	-
Milling quality	N	-	-	-	x	-	-
Starch production	N	x	-	-	-	-	-
Processing and food quality	C	x	-	-	-	-	-
Grain quality	N	x	-	x	x	-	-
Industrial demand	N	x	-	x	x	-	-
Forages		**	**	**	**	*	**
Cooperation with NARS	N	x	x	x	x	x	x
Crop residues	N	x	x	x	x	x	-
Crop Management		*	**	**	-	**	**
Soil fertility	C	-	x	-	x	-	-
Cropping systems	C	-	x	x	x	x	x
Impact and Policy Studies		*	**	**	**	*	*
Impact	N	x	x	-	x	-	-
Industrial demand	N	-	x	-	x	-	-
Food policy	C	-	x	-	x	-	-
Marketing	C	-	x	-	x	-	-
Training and Coordination		***	***	***	***	***	***
Specialized training	C	x	x	x	x	x	x
Annual workshops/field days	C	x	x	x	x	x	x
Annual program meetings	C	x	x	x	x	x	x
Regional networks	C	-	x	x	x	x	x

SCIENTIFIC STAFF POSITIONS 1989

ICRISAT CENTER

de Wet, J.M.J.	Program Director
Bidinger, F.R.	Principal Millet Physiologist
Jambunathan, R.	Principal Biochemist
King, S.B.	Principal Millet Pathologist
Mengesha, M.H.	Principal Germplasm Botanist GRU
Mughogho, L.K.	Principal Sorghum Pathologist
Nwanze, K.F.	Principal Cereal Entomologist
Pattanayak, C.M.	Principal Breeder CCRN
Peacock, J.M.	Principal Sorghum Physiologist
Stenhouse, J.W.	Principal Sorghum Breeder
Witcombe, J.R.	Principal Millet Breeder
Vacant	Associate International Cell Biologist
Prasada Rao, K.E.	Senior Germplasm Botanist
Seetharama, N.	Senior Sorghum Physiologist
Singh, S.D.	Senior Millet Pathologist
Thakur, R.P.	Senior Millet Pathologist
Agrawal, B.L.	Sorghum Breeder
Alagarswamy, G.	Physiologist CCRN
Appa Rao, S.	Germplasm Botanist
Bandyopadhyay, R.	Sorghum Pathologist
Mahalakshmi, V.	Millet Physiologist
Pande, S.	Sorghum Pathologist
Rai, K.N.	Millet Breeder
Reddy, Belum V.S.	Sorghum Breeder
Sharma, H.C.	Cereal Entomologist
Sivaramakrishnan, S.	Cereal Biochemist
Soman, P.	Sorghum Physiologist
Subramanian, V.	Cereal Biochemist
Talukdar, B.S.	Millet Breeder
Teneja, S.L.	Cereal Entomologist
Vaidya, P.K.	Sorghum Breeder
Vacant	Millet Breeder
Busso, C.S.	Postdoctoral Fellow Cell Biology
Lynch, P.J.	Postdoctoral Fellow Breeding
Osman, M.A.	Postdoctoral Fellow Physiology
Peterschmitt, M.	Postdoctoral Fellow Virology
Pinard, F.	Postdoctoral Fellow Cell Biology
Weltzien, E.	Postdoctoral Fellow Breeding
Chidley, V.L.	Senior Research Associate
Nicodemus, K.D.	Senior Research Associate
Reddy, B.P.	Senior Research Associate

ICRISAT SAHELIAN CENTER

Fussell, L.K.	Principal Millet Agronomist
Kumar, K. Anand	Principal Millet Breeder/Team Leader
Lukefahr, M.J.	Principal Millet Entomologist
Okiror, S.O.	Principal Millet Breeder/Network Coordinator
Werder, J.	Principal Millet Pathologist
Marchais, L.	Principal Geneticist (ORSTOM)
Tostain, S.	Principal Geneticist (ORSTOM)

SADCC-ZIMBABWE

de Milliano, W.A.J.	Principal Cereal Pathologist
Gupta, S.C.	Principal Forage Breeder
Gomez, M.I.	Principal Food Technologist
Leuschner, K.	Principal Cereal Entomologist
Obilana, A.B.	Principal Sorghum Breeder
Osmanzai, M.	Principal Cereal Agronomist
Rohrbach, D.	Principal Economist (IFPRI)
Sasli, H.	Principal Soil Scientist (IFDC)
Monyo, E.S.	Postdoctoral Fellow Breeding

WASIP-MALI

Adesina, A.A.	Principal Economist
Lohani, S.N.	Principal Millet Breeder (ISC)
Ramaiah, K.V.	Principal Sorghum Breeder
Thomas, M.D.	Principal Sorghum Pathologist
Vacant	Team Leader
Vacant	Network Coordinator
Hoffman, G.	Principal Striga Agronomist (IRAT)
Luce, C.	Principal Sorghum Breeder (IRAT)
Ratnadass, A.R.	Principal Sorghum Entomologist (IRAT)
Salez, P.	Principal Sorghum Agronomist (IRAT)
Beninati, N.P.	Principal Cereal Breeder (USAID)
Shetty, S.V.R.	Principal Cereal Agronomist (USAID)

WASIP-NIGERIA

Ajayi, O.	Principal Sorghum Entomologist/Team Leader
Flower, D.J.	Principal Sorghum Physiologist
Murty, D.S.	Principal Sorghum Breeder
Tabo, R.	Principal Sorghum Agronomist
Stumpo, R.	Assistant Principal Physiologist

EARCAL-KENYA

Guiragossian, V.Y.	Network Coordinator
Mukuru, S.Z.	Principal Sorghum Breeder
Laxman Singh	Principal Legumes Agronomist/Breeder

LASIP-MEXICO

Hash, C.T.	Principal Sorghum Breeder
Paul, C.L.	Principal Sorghum Agronomist/Team Leader
Clara, R.	Sorghum Breeder

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