voelkeri Fabricius, *Agonoscelis erosa* Fabricius, *Nezara viridula* L., *Mirperus jaculus* Thunberg, *Lygaeus rivularis* German, *Clavigralla tomentoscicollis* Stal. *Anoplocnemis curvipes* Fabricius. *Eurystylus* sp., *Oxycarenus* sp., *Locris rubens* Erichson, *L. erythromela* Walker and *Poophilus costalis* Walker. Other insect groups were Diptera, mainly *Chrysomia* sp. and *Sarcophaga* sp.; Dermaptera, a species of *Forficula;* Orthoptera, including *Catantops stylifer* Krauss, *Dnopherula* sp., *Kraussaria angulifera* Krauss, *Pyrgomorpha vignaudi* Guerin, and *Zonocerus variegatus* L.; and Lepidoptera, represented by the millet head miner *Heliocheilus albipunctela* de Joannis. Crop loss assessments were not made during the survey. However, it has been reported that *C. hermanniae* can cause crop losses of 18 to 75%, depending on population density (Ajayi et al. 1998), while a combination of flower beetles and *Dysdercus* caused up to 69% grain yield loss in Ghana (Tanzubil and Yakubu 1997).

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Genetics and Plant Breeding

Global Population Diallel Crosses in Pearl Millet: A New Approach to Targeted Genetic Diversification

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The global millet diallel project

Pearl millet (*Pennisetum glaucum* (L.) R. Br.) originated and was domesticated in what is now the Sudano-Sahelian Zone of West and Central Africa, but migrated to semi-arid areas of both South Asia and southern and eastern Africa at least a millennium ago. Although West Africa remains the center of maximum genetic diversity, there has been considerable evolution of the crop in its secondary centers of diversity, due both to the effects of climatic differences and to conscious and creative human selection. Important regional collections of pearl millet landraces and breeding lines were assembled by the Rockefeller Foundation in India in the early 1960s and of landrace cultivars in West Africa by the Institut francais de recherche scientifique pour le developpement en cooperation (ORSTOM). The first efforts to assemble a true global collection began only in the mid-1970s with the establishment of ICRISAT in India

The systematic use of these collections to broaden the base of national and regional breeding gene pools has been limited. Breeding efforts have largely concentrated on the exploitation of existing within-country, and (less often) within-region diversity. The exception has been the recent movement of materials from West Africa to Asia, and from Asia to southern Africa, following the assembly of the global pearl millet genetic resources collection and linked regional breeding programs by ICRISAT. This movement has largely been opportunistic, exploiting such specific landrace material as the *Iniadi* landrace of Togo/Ghana, (Andrews and Anand Kumar 1996) that confers a broad adaptation, permitting very easy inter-regional transfer.

Studies have demonstrated that the planned genetic diversification of adapted populations can produce superior base populations for the development of cultivars with improved grain and stover yields (Ouendeba et al. 1993). Recurrent selection in populations created from diverse sources is an effective and productive breeding strategy to develop superior open-pollinated varieties (Andrews et al. 1985) and hybrid parents. What is lacking is a systematic, inter-regional program to create new breeding populations from elite genetic material originating in historically separated regions of diversity, to broaden the genetic base of regional millet breeding programs.

ICRISAT millet scientists in southern Africa, western Africa, and India have initiated a new collaborative project—entitled the Global Pearl Millet Diallel Project—to initiate systematic diversification of elite regional germplasm, by making trait-based global diallel crosses. The project has three stages:

- Identifying elite landrace and breeding materials from each of the three major millet regions of diversity, that contain specific traits of importance for both adaptation and productivity, that would be of potential value to plant breeders in other regions
- Making targeted sets of diallel crosses among materials from different origins, selected by specific maturity or plant type criteria. The resulting F_1s will be supplied to regional networks, national agricultural research systems (NARS), and ICRISAT plant breeders for evaluation at their own locations, and selection of specific crosses to broaden their own gene pools
- Random-mating individual population crosses, selected by project collaborators, to produce new and diversified breeding populations for their own breeding programs, based on their own choices, and made in their own fields.

We expect that this project will result in a greater utilization and exploitation of existing elite genetic diversity (including adapted germplasm accessions) in all the three major regions of the crop's domestication, and consequently will enhance genetic diversity in national and regional pearl millet breeding programs. Specifically, this project should reduce genetic vulnerability to diseases and insect pests, provide a base for selective improvements in maturity, tillering, grain size, panicle length, etc., and ultimately increase the productivity of national and regional breeding program gene pools. These improvements should eventually result in a greater availability of varieties combining new traits and higher yield potential for farmers in the major millet-growing regions of Asia, West and Central Africa, and eastern and southern Africa.

Current status of the project

In 1998 and 1999 we assembled and evaluated at ICRISAT-India 72 elite populations and varieties from ICRISAT and NARS breeding programs in all three regions. In 2000 we produced the first of several planned population diallel crosses from selected parents from this collection—a 12 x 12 diallel of varieties bred from diversified *Iniadi* germplasm in each of the regions. The *Iniadi* type, originally from the Togo/Ghana/Burkina Faso border area of West Africa is characterized by early flowering, limited tillering, a broad panicle, and very large grain (Andrews and Anand Kumar 1996) [The *Iniadi* landrace is known by several names, depending upon the area of origin: *Igniari* (Togo), *Iniadi* (Burkina Faso), *Ignati* (Benin, Burkina Faso), and *Nara* (Ghana and Benin)]. It has proven to be especially well-adapted to poorer soil conditions and to terminal drought environments, where its low tillering habit results in a single, but productive panicle per plant. *Iniadi* germplasm is presently the single most widely used pearl millet germplasm type in the world, and has consequently been crossed to a broad range of local germplasm in all pearl millet-growing areas. Cultivars based on *Iniadi* germplasm are grown by farmers in many countries (Angola, Benin, Botswana, Chad, Eritrea, India, Kenya, Mali, Malawi, Mauritania, Namibia, Niger, Sudan, and Zimbabwe). *Iniadi* germplasm transmits its phenotype strongly to its progenies, but it is nevertheless easy to see

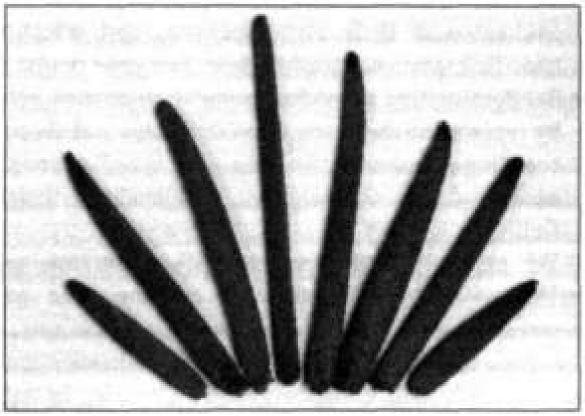

Figure 1. Variability in pearl millet panicle characteristics among the parents used in the global diallel of parents derived from crosses of *Iniadi* germplasm x locally adapted breeding lines and populations

useful variation in the basic phenotype resulting from crosses to various local germplasms and selections for locally preferred phenotypes (Figure 1).

The 12 *Iniadi-derived* parents selected for the diallel come from ICRISAT and NARS breeding programs in Asia, West Africa, and southern Africa, and have varying degrees of local parentage (Table 1). They were selected for use in the diallel on the basis of both their productivity (assessed in replicated trials at ICRISAT-India) and the diversity of their non-*Iniadi* parent(s). The productivity of tillers, rather than of the main shoot, was a major consideration, as variation in tiller biomass accounted for 80% of the variation in both grain and straw yields in the Indian-bred parents and for 60% of the variation in grain yield in the African sources. This suggests that an important consequence of the diversification of the

Table 1. Pearl millet populations and varieties derived from the *Iniadi* landrace, chosen as parents for the first global diallel cross. Yield component data are based on replicated observations, but were recorded from different experiments for the African and Indian-bred parents

Parent variety	Origin and description	Panicles plant^{-1}	Grains panicle^{-1}	100-seed mass (g)
GB 8735	Bred at ICRISAT-Niger, in collaboration with national programs of Chad and Mauritania, from a cross of *Iniadi* and *Souna* germplasm from Mali	2.9	2315	1.35
Gueriniari 1	Bred at ICRISAT-Niger from a cross between the Niger landrace *Guerguera* and *Iniadi* lines	2.4	3665	0.83
Iniari Composite	Bred at ICRISAT-Niger from a 1990 collection of *Iniadi* landraces from northern Togo	2.4	2070	1.58
ICMV-IS 903011	Bred at ICRISAT-Niger from a cross between the Niger landrace *Heinikire* and *Iniadi* lines	2.3	4475	0.72
SDMV 96051	Bred at ICRISAT Bulawayo from a cross between Okashana 1 and the Namibian landrace IP 18614	2.9	2215	1.18
SDMV 96063	Bred at the Mahanene Research Center, Namibia by the Namibian Ministry of Agriculture and ICRISAT-Zimbabwe, from the Maria Kaherero composite	3.2	3110	0.83
SDMV 96014	Bred at ICRISAT-Zimbabwe from a cross between Okashana 1 and the Namibian landrace IP 18364	2.8	3210	0.98
SDMV 95017	Bred at ICRISAT-Zimbabwe from a cross between Okashana 1 and the Namibian landrace IP 18498	2.8	2120	1.33
Medium Composite 88	Bred at ICRISAT-India from a cross of the ICRISAT Medium and Bold-Seeded Early Composites	4.3	2620	1.26
Early Composite 89	Bred at ICRISAT-India from the ICRISAT Early Composite and a variety from the Bold-Seeded Early Composite	4.8	3025	1.14
AIMP 92901	Bred by ICRISAT-India and the National Agricultural Research Project, Aurangabad, India, from the ICRISAT Bold-Seeded Early Composite and its outcrosses	2.9	3370	1.26
RCB-IC912	Bred by the Rajasthan Agricultural University, Jaipur, India, and ICRISAT-India, from the ICRISAT Early Composite 87	3.5	2810	1.05

original *Iniadi* germplasm through crossing to elite breeding materials in various breeding programs has been an improvement in its tillering ability. It is therefore likely that some of the individual crosses in the diallel will have improved tillering and thus permit selection of much better tillering lines from populations made by random-mating the crosses.

Table 1 also provides a summary of the differences in the major yield components (panicles plant^{-1}, grains panicle^{-1}, and 100-grain mass) among the parents. The data for the parents bred in West and southern African and those bred in India cannot be directly compared as they were estimated from different experiments, but they provide a general idea of the differences among the parents chosen for the diallel. There is a good variation for all yield components, with sources of higher tillering capability (Medium Composite 88 and Early Composite 89), grain numbers per panicle (ICMV-IS 90311 and Gueriniari 1), and 100-grain mass (*Iniari* Composite, GB 8735, and SDMV 95017).

Availability of the diallel

Small amounts of seed of the *Iniadi* diallel, including parents, are available to interested public and private sector pearl millet scientists for evaluation, with the completion of a standard ICRISAT Materials Transfer Agreement (MTA) that can be downloaded from the ICRISAT website (http://grep.icrisat.cgiar.org/grep/mta.htm). The completed MTA should be e-mailed, faxed, or surface-mailed to the address below, accompanied by a seed import permit, if required by the national plant quarantine service, and the date by which the material is required (allow 6-8 weeks for quarantine clearance and shipping):

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ICRISAT would appreciate receiving a copy of any evaluation or other data recorded on the diallel entries.

ICRISAT would also be willing to supply 100 grams of random-mated seed of a few selected F_1s from the diallel for use in national or regional breeding programs, based on a formal request, accompanied by a signed MTA. If a particular F_1 has already been random-mated, the seed can be supplied immediately, if not, the seed will be supplied within 6 months of the receipt of the request.

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First Forage Pearl Millet Hybrid Release in India

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The first release of a forage pearl millet hybrid in India was made by a notification issued by the Government of India on 18 December 1997. The hybrid, developed by scientists of the Proagro Seed Company, Hyderabad, India, was tested as FMH-3 by the All India Coordinated Project for Research on Forage Crops for 3 years, (1994-96), and released as Proagro No. 1. The release proposal was submitted to the Central Sub-committee on Crop Standards, Notification and Release of Varieties for Agricultural Crops, and was considered during the 29th meeting of this Committee on 24 October 1997. Proagro No. 1 has been recommended for cultivation throughout the pearl millet growing areas of India with irrigation during the hot dry summer season, under both rainfed and irrigated conditions during the rainy season, and for both single- or multi-cut purposes. It is highly resistant to downy mildew (caused by *Sclerospora graminicola* (Sacc.) J. Schrot.) and escapes ergot (caused by *Claviceps fusiformis* Loveless) and smut (caused by *Moesziomyces penicillariae* (Bref.) K. Vankyl as it is usually chopped at the booting stage.

Proagro No. 1 attains a plant height of approximately 170-190 cm. It has non-hairy nodes that are not covered by its non-hairy leaf sheaths. All plant parts (stems, nodes, leaf sheaths, and blades, etc). are green in color. The panicles are cylindrical with small bristles and shriveled anthers. It is a male-sterile hybrid and does not set its own grain. The hybrid has been purposely bred as a male-sterile so that the forage remains nutritious until chopped and the crop recovers well after a forage harvest. The hybrid is