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BRIEF REVIEW OF ICRISAT MILLET IMPROVEMENT ACTIVITIES

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THE ROLE OF THE ICRISAT MILLET IMPROVEMENT PROGRAM

The ICRISAT Millet Improvement Program aims to develop, disseminate, and assist in the utilization of technology that will enable on-farm pearl millet yields in the semi-arid tropic (SAT) to be raised to consistently higher levels that they are at present.

The term technology includes techniques, such as improved resistance screening techniques and breeding procedures, and new improved geno-types that combine sources of stress resistance and high yield potential.

To meet these objectives the program has teams of scientists working together on interdisciplinary problem-oriented projects based at the ICRISAT Center, near Hyderabad, India, and assisting in several countries in the African SAT.

Though the target is the small farmer of limited resources, the immediate clients of the Center program are the research scientists and extension personnel in national agricultural programs. The aim is to provide the clients with new technology, training, and information, so that they will be able to more rapidly provide the target farmer with the appropriate package of yield increasing technology.

STATUS OF THE PROGRAM AT THE START OF THE 1980s

Staff numbers, distribution, and organization

The team at ICRISAT Center includes 7 breeders, 3 pathologists, 3 physiologists, 2 microbiologists and a germplasm botanist, operates under the leadership of one of its senior Principal Scientists, who is responsible to the Center Association Director-Research.

The personnel in the African country programs operate under the administrative leadership of designated country-based team leaders, who are responsible through the Project-Manager of the West African Cooperative Program to the Center Associate Director-Cooperative Programs.

The role of the scientists in the country programs is three-fold: first and foremost is the responsibility to assist and contribute to the national program; secondly is the responsibility for contributing to a regional network; thirdly is the responsibility to assist in the international testing program coordinated by the ICRISAT Center.

The role of the Center-located scientists is to provide information, technology, training, and support the national program sts (including ICRISAT country program staff) need to more fulfill their functions.

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ICRISAT has pearl millet improvement staff assisting in most of the important pearl millet producing countries with the exception of Chad, which annually grows more than 1.1 mn ha of pearl millet.

THE CENTER-BASED RESEARCH PROGRAM

The ICRISAT Center-based Millet Improvement activities function at four levels:

i. the Center farm (17°N) near Hyderabad, India

ii. the Center-operated Indian sub-centers at Bhavanisagar (11°N) and Hissar (29°N)

iii. stations in Africa with ICRISAT staff

iv. national program stations with no ICRISAT staff

New methodologies and materials are developed and tested at the Center and Indian sub-centers, and the improved technology identified is fed to national programs, in India directly, and in Africa through ICRISAT-staffed centers.

The Center-operated Indian sub-centers are of vital importance in the system of initial screening, for with them, and the Center itself, the performance of materials can be evaluated at the range of latitudes over which pearl millet is predominantly grown.

Major emphasis is given to the identification and utilization of resistance to the major factors that reduce pearl millet yields, and to combining these resistances with agronomic eliteness and high yield potential.

PROGRESS IN IDENTIFICATION OF RESISTANCE TO MAJOR YIELD CONSTRAINTS

A. Diseases

1. Downy mildew

i. Sporangia were shown to play a major role in the epidemiology of pearl millet downy mildew (DM) and the information was used to develop an effective, large scale, field resistance screening technique, which is now being used in several national programs.

ii. A cooperative international network, established to test the stability of DM resistance identified at the Center, has shown: i. DM to be more severe in Nigeria, Niger, and Upper Volta than in India and Senegal, and there are differential reactions among stations in Nigeria, Niger, and Upper Volta, probably due to the presence of more virulent physiologic races,
ii. there are sources of stable resistance to DM that have been resistant at all locations in several years of tests (SDN-503, 700516, P-7, P-10), and these originate in northern-Nigeria and southern-Niger. Seed of these resistant lines have been supplied to scientists in many national programs.

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iii. The breeding and pathology members of the team have jointly operated a 6 ha DM screening nursery in two seasons each year since the 1976 rainy season, in which all breeding lines are evaluated, and in which S_1s and full-sibs are made in the population improvement program. As a result of this exercise virtually all ICRISAT breeding lines now carry high levels of DM resistance that is effective in India. This has been most valuable to demonstrate the importance of interdisciplinary work, and the need to have an effective screening system to minimize escapes.

iv. Several DM resistant lines have been developed from the super-susceptible, but the valuable $_3DD_2$ source following irradiation and mass screening in the DM nursery.

v. Hybrids produced with pollen from population products (top-cross hybrids) appear to be more DM resistant in West Africa than single cross hybrids.

vi. A cooperative project has been established with the University of Reading, England, with funding by the British Overseas Development Administration, to study the pathogenic variability of the DM pathogen from many countries in the SAT.

vii. Good potentials for DM control have been identified by seed treatment with various formulative of the new system fungicide "metalaxyl".

2. Ergot

i. An effective large-scale resistance screening technique was developed, and scientists from the Indian national program have visited ICRISAT center to learn the technique.

ii. No source of a high level of ergot resistance was identified from the germplasm, but more than 20 resistant lines have been developed by pedigree selections among progeny of crosses between relatively less susceptible lines. These are now at the F5 stage and F6 seed is available to national program scientists.

iii. Most of the ergot resistant lines developed carry high levels of DM resistance, and resistance to smut.

iv. Information discovered on the interference of pollen in the ergot infection process contributed to the development of the screening technique, and to the establishment of experiments that indicate a pollen donor can be used to reduce ergot in a hybrid crop.

3. Smut

i. Hissar, was identified as the location for the major smut screening work, and smut resistant lines identified there have been confirmed as reistant in multilocational testing in India, Senegal, and Upper Volta. The best entries include ICI 7517-S-1, P-10-S-1, WC FS 151-S-1-1, SSC 229-4-1-S-6-1 and EB 229-4-1S-6-1.

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B. Drought

The effort has been concentrated on the development and utilization of field screening techniques.

Despite problems of inducing uniform drought stress, and uncontrollable breaking of stress by untimely showers, progress has been made in identifying drought resistant or avoidant genotypes. This has been good start, but we are a long way from the production of high yielding cultivars with high levels of drought resistance.

Work is being intensified to:

- identify better screening techniques - the linesource system is being evaluated at the present time
- to examine the effectiveness of selecting in segregating populations under drought stress
- to examine the consistency of results over seasons and years
- to examine the relevance of reactions in summer to reactions during natural drought in the monsoon season.

C. Low fertility

1. Nitrogen fixation

Pearl millet is grown predominantly on light, sandy soils, with little or no fertilizer applied, except for the compost around villages.

In our program emphasis has been placed on the evaluation of the potentials for enhancing biological nitrogen fixation associated with the pearl millet rhizosphere.

There have been, and still are, problems in the reliability of the indirect assay method for nitrogen fixation, but cultivars that show consistently high nitrogenase activity have been identified. Micro-organisms that fix nitrogen have been isolated from around pearl millet roots, and some apparently occur inside the roots.

We are however, a long way from the development of cultivars with proven ability to fix large amounts of nitrogen, and a much more concentrated effort is needed if we are to rapidly exploit this important field.

2. Selection in low fertility soils

A project has been initiated to evaluate the potentials for breeding and selection predominantly under low soil fertility, in comparison with the present system of breeding and selection under moderate to high soil fertility levels.

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PROGRESS IN THE PRODUCTION OF ELITE BREEDING PRODUCTS

Recurrent selections in composite populations and variety-cross approaches are equally emphasized in generating hybrids, synthetics, experimental varieties, and inbreds, as well as an array of breeding lines to be distributed to cooperating breeders in various countries.

A. Composite Breeding

1. Intrapopulation Improvement

In each cycle of selection, experimental varieties and individual best progenies are generated as the practical outcomes of selection. Experimental varieties are derived by combining the 5 to 8 best progenies of an individual test location (location-specific experimental variety), or the 5 to 8 best lines over all test locations (across-location experimental variety). Selected individual progenies are also evaluated in testcrosses with male-sterile lines to identify potential restorers for producing hybrids.

In 1978, five ICRISAT experimental varieties were tested in the All India Coordinated Trials - two (SSC-H76 and MC-P76) were in the Initial Population Trial, and three (WC-C75, IVS-A75, and MC-C75) were in the Advanced Population Trial. All did well in their respective trials. SSC-H76 (1952 kg/ha) and MC-P76 (1792 kg/ha) ranked first and fourth among the test entries in the Initial Population Trial, and were promoted to the advanced trial in 1979. WC-C75 (2073 kg/ha), IVS-A75 (2008 kg/ha), and MC-C75 (1972 kg/ha) ranked first, second, and fourth respectively among the test entries in the Advanced Population Trial; the latter two were retained in the advanced trial for the second year in 1979. WC-C75, which ranked first on the basis of three years trials with an overall mean yield of 1731 kg/ha (which was 94 percent of the commercial hybrid BJ 104) was moved to the minikit demonstration trials of the All India Program in 1979. These results have shown the importance of recurrent selection as a means of rapidly improving millet populations and have shown that varieties can be produced with the yield potential of hybrids.

The success in our composite breeding program has led to the adoption of the recurrent selection techniques in several millet breeding programs in India.

In Africa, however, our experimental varieties have not shown significant superiority over local varieties, although in certain locations some of them gave better yields than the local checks in a certain year, but this did not hold in the following years when the environmental conditions changed. We have feed-back from our breeders in Africa that material bred at ICRISAT Center are not well adapted to many of the African locations mainly because they are too early, which results in severe attack by smut, ergot, and birds; are susceptible to local races of downy mildew.

It seems unlikely that the recurrent selection program in India will lead to final products superior to the best improvement local varieties in many African countries. With seven ICRISAT millet breeders posted in Africa, working with national program breeders this should not cause major problems.

2. Interpopulation Improvement

The interpopulation improvement project primarily aims for the production of superior hybrids, however, experimental varieties can also be generated as a side-line product.

At present , 4 composite pairs are being improved by this method. One cycle of reciprocal full-sib recurrent selection was completed in one pair (IR/IB) from which promising hybrids have been identified for further testing. The other three pairs are still in the first cycle of selection. The project is too recent to produce an outstanding product, but is expected to yield fruitful results in the long run.

3. Basic Studies Related to Population Improvement

In order to provide pearl millet breeders with information on the relative values and efforts involved in different methods of recurrent selection, a 6-year study was initiated in 1976 to compare four principal methods of recurrent selection - gridded mass selection, recurrent restricted phenotypic selection, full-sib progeny selection, and S_2 progeny selection. The World Composite was chosen for this study, and selection is now underway. Final comparison will be made after completing three cycles of the S_2 progeny selection and six cycles of the other three methods.

We have also investigated whether experimental varieties and individual progenies will maintain the same yield levels in advanced generations. The results varied from entry to entry from a slight decrease to a slight increase but the majority maintained the same yield levels in the succeeding generations.

Another study is underway on procdures by which national breeders could effectively improve the experimental varieties which still contain sufficient variability for further selection. A study on a suitable number of progenies to form an experimental variety is also in progress.

B. Variety Crosses and Synthetics

This project represents much of the "Conventional" breeding approach, in which inbred or partially inbred lines are generated by crossing complementary inbreds or varieties followed by pedigree selection for two or three generations till a degree of uniformity is attained. The lines so produced are tested for use in synthetics, as potential hybrids parents, and for performance per se. Selected lines with a range of diversity are distributed to cooperating breeders annually in the form of Uniform Progeny Nurseries, providing a continuous supply of useful clear-cut variability to national programs.

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A synthetic is formed by combining a number of inbred or partially inbred lines (mostly 4 to 8) selected on their per se performance or combining ability from diallel cross or inbred tester analysis.

Synthetic ICMS 7703, performed well in the AICMIP Initial Population Trial in 1978, and was promoted to the Advanced Population Trial in 1979. This synthetic was the highest yielding entry in the 1978 IPMAT Trial at Serere (5061 kg/ha), and Ukiriguru (2978 kg/ha).

The results from the 1979 Advanced Synthetic Trial also indicated that we have newer superior products coming out from this project, some of which have low incidence of downy mildew across locations, including Kano and Samaru in Nigeria where DM is most severe.

C. Hybrids

The hybrid project aims to develop parents for high-yielding disease resistant hybrids. Inbreds, or partial inbreds, generated from the recurrent-selection, source-material, and variety-cross projects are routinely tested for their potential as hybrids parents.

Three stages are involved in identifying superior hybrids. Initially test crosses are evaluated in single plots at ICRISAT Center. Selected hybrids are entered in the initial hybrid trial, which is a replicated trial at several locations including the DM nursery. Hybrids which display high yield potential, show stability across environments for yield and downy mildew resistance, and are agronomically satisfactory, move forward to the advanced stage of testing at a larger number of locations, including African locations critical for identification of stable disease resistances. The best hybrids from the advance trial are more intensively evaluated in the ELVT, IMPAT, and national testing programs. Hybrids that have done well in multilocational trials in certain African locations are ICH 165 and ICH 118.

FUTURE RESEARCH ACTIVITIES

The basic role of the program, as indicated above, is to develop, disseminate, and assist in the utilization of technology that will raise pearl millet yield in the SAT to consistently higher levels than they are at present.

The program should not compete with national programs in doing those things which they can do easily and well, but should concentrate on providing scientists in national programs with new improved materials and methodologies that will enable them to more rapidly and effectively contribute to the farmers they serve. The requirements will vary, depending on the degree of development and the needs of a particular country program.

The center-based program needs in the 1980s to concentrate more effort on studies that will eventually lead to a whole new generation of varieties and hybrids far superior to those presently available, and be less concerned with the immediate production of finished or near finished products.

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A week-long International Pearl Millet Workshop was hosted by ICRISAT in 1977, with 50 participants from 16 countries. Another International Workshop is scheduled for 1981.

Organization and participation in trials

The Center program organizes several international trials for yield performance and disease resistance each year, which, in addition to providing the information on genotype performance, are a means of promoting distribution of useful genotypes, and of information and seed exchange. The trial reports are generally prepared by March or April of the year following the trial, are distributed widely, and are utilized by national program scientists as evidenced by the seed requests received following distribution of the reports.

The West African program scientists have been encouraged to organize a regional trial that will serve better the needs of the region, and regional trials were started there in 1978.

Elite products from the ICRISAT Center program are contributed to the Indian national program trials, and as indicated above, some varieties and synthetics have performed well in these trials. It takes a minimum of 5 years for varieties to move through the Indian trial system to release for farmers, and so it is not yet possible for our materials to be contributing directly in the Indian farmers fields.

Seed exchange

Since 1975, more than 11 000 items of breeding materials and disease resistance sources (exclusive of requests for germplasm and the entries in international trials) have been sent to requestors from 49 countries. In 1978, 1719 breeding materials consisting of inbreds, restorers, hybrids, synthetics, composite bulks, composite progeny, experimental varieties, and male-sterile lines were requested by Indian scientists, and in 1979 more than 200 disease resistance sources were requested.

Training

Training has been, and will continue to be, an important aspect of ICRISAT's program. Training will continue at several levels, from short term courses to learn specific skills to long term scholarships to complete thesis work for higher degrees. ICRISAT has an arrangement with the nearby Andhra Pradesh Agricultural University, for students from abroad to take course work for a higher degree at the university and to do the thesis work at ICRISAT.

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