SUMMARY OF PROGRESS IN SORGHUM IMPROVEEMNT

1974 - 1981

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(ICRISAT)
International Crops Research Institute for the Semi-Arid Tropics
ICRISAT Patancheru P.O., Andhra Pradesh 502 324, India

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SORGHUM GERMPLASM

The sorghum germplasm assembly work at ICRISAT began with the acquisition of 9861 lines from the World Collection assembled by the Rockefesser Foundation in India. Since then ICRISAT has assembled an additional 12303 accessions. At present 21,264 accessions from 78 countries are being conserved in the ICRISAT Genetic Resources Unit which is the large of world repositories. Inspite of this, the world collection is deficient in some priority areas which much be covered as a matter of urgency.

In accordance with the recommendations of the IBPGR Advisory Committee on Sorghum and Millets, collection expeditions were organised in Tanzania, Malawi, Zambia, Somalia, Botswana, Mozambique, Ghana and certain pockets in India which were not collected earlier. Several important landraces were added to the collection. Pointed collections were organised in south-eastern Sudan and Gambella area of Ethiopia and a good number of 'Zera-zeras' were collected. Zera-zera sorghums are highly prized for their yield, disease resistance and grain quality.

Most of the accessions were evaluated for important morpho-agronomic descriptors. 'Sorghum Descriptors' recently published in collaboration with IBPGR will promote a more systematic and uniform system of evaluation around the world, which will in turn enhance a common language and better understanding among sorghum improvement scientists. Screening sorghum for resistance to insects, disease, Striga, and drought and grain quality has been carried out in collaboration with other disciplines.

For more effective utilization of germplasm in sorghum improvement programs, a basic collection comprising of about 1,000 lines was established. For an effective and easy flow of tropical germplasm into various sorghum improvement programs around the world, an introgression and conversion project has been initiated. The supply of seed material to sorghum improvement scientists around the world is one of the major responsibilities of ICRISAT and so far 117,231 samples have been distributed from the ICRISAT gene bank.

INSECT PEST PROBLEMS

SHOOT FLY

Large scale breeding of the flies from the damaged sorghums revealed that more than 99 percent of all shootflies bred were Atherigona soccata. In all 13 species were bred from sorghum. A. soccata has been reared from 22 alternate hosts.

Fish meal is used to monitor shoot fly populations at ICRISAT Center since 1974. The chemical components responsible for shoot fly attraction are not known. In cooperation with the Max-Planck-Institut, Munich, we are testing fractions and residues. Recently one compound tested has been shown to be significantly more attractive to shoot flies than the standard fish meal. Spring sowing at Hissar has provided a valuable off-season testing opportunity.

We have screened 10542 germplasm lines in our search for sources of resistance to shoot fly, of which 213 lines have been selected as low susceptible. Some of the selected lines have been used in the breeding program, and three lines IS-923, IS-2195 and IS-2312 have performed well in the All India Coordinated Sorghum Improvement Project (AICSIP) Trials.

In breeding for shoot fly resistance 158 advanced breeding lines with good agronomic traits showed shoot fly resistance under varying fly pressures over seasons. Twenty of them were selected by AICSIP for multilocational testing in India. The same set of lines has been provided to ICRISAT cooperative programs in Africa, and also to other cooperators outside India.

STEM BORER

Stemborer (Chilo) populations are being monitored at ICRISAT Center using synthetic pheromone obtained from TPI London. The aldehyde component of the female pheromone has been found to be more attractive to male moths than the alcoholic component. Studies on the larval carryover showed that larvae were able to aestivate upto 250 days. A number of natural enemies of the larvae have been recorded at ICRISAT Center.

Large-scale field screening for resistance to Chilo stem borer using laboratory reared insect has been developed to the stage where it is now a routine technique. Populations of stemborer are high at both Hissar and Pantnagar and provide a valuable screening opportunity where natural infestation is effective at all stages of stemborer development. Of the 7684 germplasm lines screened 917 lines have been selected for further testing. Some lines have been selected as low susceptible to both shoot fly and stemborer.

MIDGE

Midge populations and incidence levels are being monitored continuously through fortnightly plantings at ICRISAT Center and Dharwar. Maximum midge activity and incidence levels are recorded on the crop sown during the first fortnight of August. The maximum diurnal activity of midge has been recorded between 0930 to 1030 hrs. Four Hymonopterous parasites have been recorded on the midge larvae.

Major emphasis is on developing a suitable midge resistance screening technique. We are able to increase midge populations to threshold

level with the help of mixed maturity plant populations sown 20 days earlier than the test material. To overcome the constraint of varying day-to-day midge populations and the differing flowering periods of germplasm and breeding lines, a caging technique has been successfully tested.

Over 1,000 lines were screened for midge resistance under natural conditions and by using the caging technique. Five lines -- IS-1335, IS-18830, IS-8713, IS-8544 and IS-8721 -- showed repeatable levels of resistance.

In the breeding project 278 advanced progenies, involving mostly DJ-6514, AF-28 and IS-12573C as midge resistant sources, were found to be tolerant to midge; 56 of them are in good agronomic backgrounds.

EARHEAD BUGS

Damage to earheads by head bugs from emergence to grain ripening has been attributed to four mirid species (Calocoris angustatus, Creantiades pallidus, Eurystylus vellevoyei and Campyloma sp.). Calocoris is the most important species and its populations are much higher in sorghum grown on vertisols as compared to alfisols. Calocoris females lay the eggs in glumes and the total development is completed in 15-20 days.

Creantiades females lay the eggs in milky grains. Two egg parasites have also been recorded.

Over 300 lines with low susceptibility to shootfly, stemborer and midge have been observed to be less damaged by headbugs. These lines are being retested to confirm their low susceptibility.

Resistance to earhead bugs was confirmed in 50 advanced breeding progenies. One of these lines, PHB 156 was resistant to the head bug complex at a number of locations in Africa, and is included in the West African regional yield trial.

ARMYWORM

Regular monitoring of the adult and larval populations of armyworm showed that the population increases with the onset of the monsoon and reaches its peak during August-September. The insect has been successfully cultured in the laboratory on natural host plants and using artificial diet. The damage levels of the armyworm were found to be higher in weedy than in weed free fields. It was found that neem kernel powder and alcoholic extracts can be used as antifeedants and result in lower levels of crop damage.

DISEASE PROBLEMS

GRAIN MOLDS

Grain molds have received considerable attention since 1974. The major causal fungi have been identified as *Fusarium moniliforme*, *F. semitectum*, *Curvularia lunata* and *Phoma* sp.

An effective large-scale field screening technique for resistance to grain molds has been developed, and is routinely used to screen germplasm and breeding lines at ICRISAT Center. Most of the germplasm lines that set seed in the rainy season at ICRISAT Center have been screened and evaluated. Several lines with low susceptibility to grain molds have been identified. These lines have maintained their low susceptibility in several years of testing at a number of locations through the international sorghum disease resistance testing program.

In the breeding program grain mold resistance sources have been utilized to produce high yielding genotypes with good grain quality and low susceptibility to molds. A large network of international testing of these genotypes has enabled many breeders in national programs to select material for their own use.

SORGHUM DOWNY MILDEW

We have had difficulty in producing consistently high levels of downy mildew in known susceptibles on a field-scale at ICRISAT Center for effective screening of germplasm and breeding material. Our epidemiological studies have shown that the major part of this difficulty is due to unfavourable temperature and humidity for infection when plants are at the most susceptible stage. Our recent work at Dharwar, a cooperative station in India, has proved the usefulness of this location for downy mildew development and all large-scale field screening willin future be conducted there.

Greenhouse screening using conidial inoculum from infected leaf pieces is routinely used for preliminary screening of material. We have identified absence of downy mildew infection in QL-3 and three sister lines. This resistance has remained stable in five years of international testing at locations where downy mildew occurs regularly and at high levels of infection. QL-3 and its sister lines are now used in the ICRISAT breeding program and in national programs in India and elsewhere for breeding agronomically elite downy mildew resistant material.

CHARCOAL ROT

Charcoal rot (which is often seen as lodging) is a disease of great destructive potential on improved, high yield potential cultivars when moisture stress occurs during grain filling.

During the first two years (1978-1980) of research on this disease emphasis was on routine screening of germplasm and breeding material for resistance using the tooth pick inoculation technique developed for maize stalk rot diseases. Although some resistant material was identified, the resistance was not stable. A number of factors are responsible for this, but the most important one was our lack of knowledge and understanding of the interactions between the pathogen, the environment and the crop's physiology as affected by its management. The major thrust of research is now in this area with the ultimate goal of providing conditions for consistant charcoal rot development on susceptible material for effective evaluation of test material in the field.

LEAF DISEASES

Elite sorghum cultivars must possess stable resistance to a number of leaf diseases if they are to perform consistently well over a broad range of environments and over an extended time period. Experience gained from our international testing program shows that leaf blight, sooty stripe, anthracnose, zonate leaf spot, rough leaf spot, rust and grey leaf spot are the diseases with great destructive potential.

We are developing resistance screening procedures for leaf blight, rust and anthracnose. We are now able to screen for leaf blight at ICRISAT Center, rust at Dharwar and anthracnose at Pantnagar. Good levels of combined resistance to the three diseases have been identified in both germplasm lines and breeding material. We are working with colleagues overseas to develop screening procedures for sooty stripe and grey leaf spot.

In the International Sorghum Leaf Disease Nursery began in 1976, several lines have shown stable resistance to at least three leaf diseases. These lines are valuable for the breeding programs.

PHYSICAL ENVIRONMENTAL PROBLEMS

DROUGHT

During 1975-79 we developed suitable empirical field screening techniques to evaluate germplasm for drought resistance making use of dry season as well as drought-prone locations within SAT. So far 1255 germplasm lines from 13 countries have been screened and 32 lines are finally being used in the breeding program. Early generations screened at ICRISAT Center are evaluated in multi-locational trails in India and Africa.

The line source sprinkler irrigation technique is successfully utilized to test the advanced progenies for drought resistance. It is encouraging to note that several of our germplasm selections and advanced progenies like SPV-351 have combined both high yield potential as well as least decline in yield under stress.

Summer planting with irrigation only at sowing is used to screen for severe water and heat stress resistances by visually scoring for leaf firing. Normal rainy season crop in 1980 at Anantapur (drought-prone location of APAU) has shown that summer screening under heat and water stress is useful; several resistant cultivars with agronomic value in a range of height and maturity have been selected.

Various plant attributes and physiological mechanisms (other than simple escape; such as avoidance, tolerance and ability to recover) desirable under a particular pattern of stress is being studied in order to evolve simple selection criteria. Techniques are being developed to screen for better rooting pattern (either in 'brick-chambers' or in nutrient cultures) and to quanitfy the degree of plant water and heat stress.

Rabi Sorghum in India. Sorghum grown under receding soil moisture conditions on vertisols during post-rainy season is of special importance to SAT India. Cultivar difference in yield stability in rabi even under conditions of delayed sowing (cold tolerance ?) is demonstrated. The plant characteristics identified as useful for rabi sorghum are: ability to decrease osmotic potential, retranslocation of stem reserves to the grain and conservation of soil moisture early in the season by suitable pattern of leaf area development. Attempts are made to diversify narrow genetic base by crossing with 32 germplasm selections (out of 7251 lines screened) from different geographical regions. Several advance progenies yielded better than checks both at Hyderabad as well as in Bijapur (in Karnataka State) in 1980.

CROP ESTABLISHMENT

Simple and effective methods have been developed for screening for seedling emergence through soil crust and under low soil water and high soil surface temperature. Lines with good seedling vigour (for which the visual scoring technique had been established) also generally have better ability to emerge through crust. The technique of screening

genotypes at seedling stage has already been extensively used to screen germplasm and breeding lines; it relies on scoring for wilting, recovery and survival of seedlings grown in bricades in the open or in the small containers in the glasshouse. Water is given once following sowing and not again until severe wilting occurs.

On average, sorghum lines with the simple morphological trait 'glossy' show higher levels of resistance to drought at seedling stage than non-glossy lines. Glossy lines like IS-1096, IS-4405 and IS-5642 show resistances to shoot fly and drought. Some glossy lines resistant to drought at the seedling stage are also resistant to drought at later stages. An intensive study is underway to understand the genetics of the glossy trait and how it can be used in sorghum improvement.

PLANT NUTRITION

SELECTION FOR NITROGEN AND PHOSPHORUS EFFICIENCY

Large genotypic variations were found for nitrogen and phosphorus uptake and retranslocation to the grain from vegetative parts. However the selection for both high biomass and harvest index automatically included selection for traits concerned with efficient nutrient (N and P) use.

Preliminary trials indicated that selection made under low fertility conditions as opposed to selections under high fertility did not confer any additional yield advantage under low fertility (comparable to farmer's) conditions. Hybrids were generally superior and more stable under low fertility conditions than varieties. Varietal performance was much affected by rainfall pattern and drought stress under both high and low fertility levels.

NONSYMBIOTIC NITROGEN FIXATION

Our field screening of germplasm and breeding material showed that there was host plant variability in stimulating nitrogenase activity. About 14% of the 334 lines of field grown sorghum examined stimulated high nitrogen fixing activity. Fifty five percent of the lines stimulate activity that is several fold greater than that in soil without roots. There is much variability in the activity between plants supposedly of the genotype, between assay occasions and between seasons. We have developed an assay system based on growing plants in pots or in test tubes that reduces this variability. We are presently determining the correlations

between these assays.

Preliminary evidence suggests that if one parent in a hybrid has high activity then the hybrid will also be active.

We have shown that nitrogen fixation by bacteria associated with sorghum grown in pot culture can contribute to the nitrogen taken up by the plant. Positive nitrogen balances have been obtained for sorghum grown in Alfisol soil or vermiculite.

Long term field experiments have been started to measure the nitrogen balance involved in continuous sorghum production.

We have isolated many different types of bacteria (at least 22) which fix nitrogen in the root zone of sorghum. Azospirillum spp are only present in some soils but even then are not a major component of the rhizosphere population.

Methods for culturing, counting, and identifying nitrogen fixing bacteria have been developed but more work on this aspect will be undertaken with a collaborative project with Philipps University, Marburg, financed by GTZ.

Inoculation with nitrogen fixing bacteria has increased dry weight and yield of sorghum grown in pots of soil or vermiculite.

FOOD QUALITY

Utilization surveys indicated that sorghum grain is consumed in the SAT as eight basic foods: unleavened bread, leavened bread, thick porridge, thin porridge, boiled grain, steam cooked products, snacks and beverages. Food product (roti, ugali, to, sangati, soru, pops) evaluation of numerous sorghum cultivars showed that considerable genetic variation existed among pearly white grain types for the preferred quality attributes.

Physico-chemical and food quality attributes of a common set of cultivars for several food products were evaluated in collaboration with several scientists from Africa, Central America and USA. Grain color and endosperm texture appeared to be primary factors that determined food quality.

Rapid methods for the estimation of protein and lysine in sorghum grain have been standardized, and are used to determine nutritional value of the grain.

IMPROVEMENT OF SORGHUM POPULATIONS

In 1973 a large number of sorghum populations were introduced from Purdue and Nebraska Universities in the USA, Serere, Uganda and Samaru, Nigeria. These were evaluated and synthesized into nine populations. After two cycles of recurrent selection on these, four of the populations were dropped leaving five populations: US/R, US/B, Rs/R, Rs/B and West African Early, which were subjected to rigorous selection with the objective of improving them for grain yield and stability, grain quality, agronomic desirability and resistance to economically important pests and diseases.

During the first cycle of recurrent selection, S_1 progeny testing was used but this was abandoned for S_2 progeny testing in subsequent cycles. The selection intensity varied from cycle to cycle but was generally between 15 and 20 per cent.

Significant progress has been achieved towards improving the populations for agronomic desirability and grain yield and quality. Studies conducted on two populations US/R and US/B to find out the effect of selection on grain yield, plant height and maturity have revealed that grain yield in both populations was significantly increased at rates ranging from 13 to 19% for US/R and 7 to 14% for US/B per cycle. At C_1 both populations yielded significantly more than CSV-4 variety while at C_3 both populations attained grain yield levels comparable to or better than CSH-6, a commercial hybrid. Genetic variability for grain yield of both populations at cycle 3 was not significantly different from the base populations. This indicates that continued selection for grain yield in both populations

would be expected to be effective. Genetic variability for plant height and maturity was considerably reduced.

New sources of resistance to pests, diseases, Striga, etc. are continuously being injected into all populations to increase the genetic variability and plant resistances in these populations.

Promising lines have been extracted from these populations and a number of them have performed well in many national programs. A variety derived from the population has been released as Melkamesh in Ethiopia. Rs/B-8785, Ind-Syn-387-1, GG-1483 and GG-1485 varieties extracted from populations are in the advanced stages of testing in India and other countries. Several lines extracted from improved populations are still in the process of purification and testing and are expected to be more superior in performance and adaptation than lines extracted from the base populations. A large number of lines extracted from non-restorer populations have proved to be good non-restorers and the most promising of these are being converted to male-sterility. Extracted lines from the restorer populations are being evaluated in hybrid combination on existing commercial female parents.

DEVELOPMENT OF HYBRIDS

A modest sorghum hybrid project was started in 1978 and concentrated mainly on testing the best varieties from various breeding projects as potential restorers on standard Indian commercial male steriles: 2219A, 2077A and 296A. This was later expanded to include a wide range of varieties as improved hybrid parents. In 1981 this project is being expanded further to include the assembly of all reported non-milo male-sterility inducing cytoplasms, search for restorers on new male-sterile cytoplasms, and an attempt to locate new male-sterile inducing cytoplams.

A large number of hybrids from all breeding projects have been evaluated at Patancheru, Bhavanisagar and Dharwar. A few selected promising hybrids have been evaluated at several locations in Africa.

Several hybrids have performed well in India as compared to the commercial hybrids CSH-5 and CSH-6. ICRISAT hybrids SPH-185, SPH-187 and SPH-188 out yielded the commercial hybrids CSH-5 and CSH-6 in the AICSIP preliminary hybrid trial and were recommended for further testing in the advanced hybrid trials in 1981. Five hybrids on 2219A, five hybrids on 2077A and three hybrids on 296A significantly outyielded commercial hybrid checks at three sites in India in Kharif 1980. We have contributed all the thirteen hybrids for further extensive testing in India in the AICSIP preliminary hybrid yield trials. The male and female

parents of our hybrids exhibit good nicking for flowering to ensure ease in seed production.

The available female parents have a limited range of maturity and most are poor in grain quality and resistance to diseases and pests. We are attempting to develop female parents with these desirable attributes. A number of good potential seed parents have been identified and are being converted to male-sterility using the backcrossing substitution method. In addition more and more potential restorers are continuously being identified in the various breeding projects. These are being testcrossed and evaluated.

INTERNATIONAL SORGHUM YIELD TESTING

International sorghum testing was initiated in 1975 with the following objectives:

a) To evaluate a diverse array of elite varieties with good grain quality and yield potential over a wide range of environment in SAT to identify varieties with wider adaptation and stable yields.

b) To provide improved varieties and valuable breeding lines to national programs for evaluation in national trials for local adaptation and utilization in national breeding programs.

Initially the sorghum international trials were composed of yield nurseries of promising introductions and population progeny evaluation trials. In 1977 these were replaced by Sorghum Elite Progeny Observation Nursery (SEPON) and the International Preliminary Yield Trial (ISPYT). In 1978 ISPYT was divided into ISPYT-1 and ISPYT-2. ISPYT-1 includes the early-maturing types while ISPYT-2 includes the medium to medium-late maturity types. Additional international trials have since been added and these include the hybrid, B-line, advanced variety, Striga resistance and drought resistance trials. A wide range of improved varieties and hybrids have been evaluated and several of these are contributing to national sorghum programs in the SAT.

In 1977 Rs x VGC, Fast Lane 'R' 101, Bulk 'Y' 31 and Rs/R-20 all from ISPYT performed well in Ethiopia. Rs x VGC was most outstanding and was selected for inclusion in the national trials. FLR-101 performed well in Mali, Thailand and India. Several entries from SEPON performed well across locations especially the derivatives from crosses involving SC-108 most of which were selected in Upper Volta, Niger, Senegal, Mali, Kenya, Thailand, Tanzania, Mexico and India.

In 1978 US/B-292, GG-1485 and Bulk-Y-138 from ISPYT performed well at locations in Africa. (SC-108-4-8 x CS-3541)-43-1 from SEPON yielded well in Mali, (SC-108-4-8 x CS-3541)-88-1, (SC-108-3 x CS-3541)-3-1 and (SC-108-4-8 x CS 3541)-13-1 all from SEPON yielded well in Upper Volta and CS-3541 x 2KX6-2 yielded well in the Sudan.

In 1979 FLR-1379-1-1 from ISPYT-1 significantly outyielded local checks in Sudan, Botswana, Malawi, Tanzania, Thailand and India. (FLR-141 x CS-3541)-2-1-5 and (FLR-101 x CS-3541)-3-2-1 yielded well at most locations in India and Africa. Lines (SC-108-3 x Swarna) x E12-5-4 and (SC-423 x CS-3541) x E35-1-2 from SEPON produced the highest mean yields at 10 African and Southeast Asian locations. A line from Diallel population, Diallel pop 7-862 is released as Melka mash for Ethiopian lowlands.

In 1980 (SC-109-3 x CS-3541)-19 yielded highest in the AICSIP advanced variety trial and was recommended for regional demonstration in India. (SC-108-4-8 x CS-3541)-88 and (IS-12611 x SC-108-3)-1-2 yielded well in AICSIP preliminary variety trials and were advanced to AICSIP

advanced variety trials. Population derived lines Ind-Syn-387 and Rs/B-8785 yielded well in the AICSIP preliminary variety trials and were recommended for inclusion in the 1981 advanced variety trial. GG-1483 and GG-1485 produced substantially higher grain and fodder yields than CSH-8R during the AICSIP post-rainy season advanced variety trial and were recommended for further testing during the 1981 post-rainy season.