# BIOTECHNOLOGY FOR
# DRYLAND AGRICULTRURE IN ANDHRA PRADESH
## *ASSESSING NEEDS AND OPPORTUNITIES*

**PROCEEDINGS OF THE WORKSHOP**

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## ICRISAT'S CROP IMPROVEMENT AND RESOURCE MANAGEMENT RESEARCH : RELEVANCE TO ANDHRA PRADESH

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### 10.1 INTRODUCTION

In establishing the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in 1972, the Consultative Group for International Agricultural Research (CGIAR) chose Hyderabad, India as ICRISAT's headquarters, it being a location broadly representative of the world's semi-arid tropics (SAT). ICRISAT's research began in earnest at the Patancheru farm site, straddling Alfisols and Vertisols typical of the SAT, in 1974. ICRI-SAT's
millets, sorghum, groundnut, chickpea and pigeonpea, and improvement of agriculture generally in SAT regions.

Over the previous few years, ICRISAT scientists have been intensively involved in a research prioritization process aimed at evolving as viable and relevant a research portfolio as possible
opportunities of Andhra Pradesh, along with those of the rest of the SAT and other major growing regions for the ICRISAT mandate crops, was very much part of this exercise. A closer examination of the outcome of this effort, than can be presented in this paper, should contribute to the objectives of this Workshop. Essentially, we identified a set of research themes and prioritized them using criteria of efficiency (e.g. benefit/cost ratio of a research endeavor), equity (addressed to poverty alleviation), internationality (how widespread the problem is) and sustainability. In developing our project portfolio for 1994-98, we focussed these themes on specific production systems. The production system concept allowed us to better target real-life situations and identify specific areas in which to assess the impact of our research.
environmental resources, the key elements of the major farming systems therein and important issues or constraints to improving productivity. For example, the Nalgonda and Mahaboobnagar districts of Andhra Pradesh (A.P.) fall primarily in production system 9 according to ICRISAT's classification.

In this paper, we briefly focus on ICRISAT's endeavors, past, present and intended that are of possible relevance to A.P. in general and Nalgonda and Mahaboobnagar districts in particular. We document some existing technologies and research findings of relevance, examine prospects for their eventual impact at the farmers' field level and focus on areas where recent advances in biotechnology could play an increasingly important role. Space limitations prevent other than a summary being presented here, but those interested in further details are referred to the relevant ICRISAT publications.

## 10.2 GENETIC RESOURCES

One of the major objectives of ICRISAT is to serve as a repository for the world collections of germplasm of its mandate crops. So far, ICRISAT had assembled 111 674 germplasm samples, consisting of 34 366 sorghum, 25 213 pearl millet, 17 091 chickpea, 12 393 pigeonpea, 14 051 groundnut, and 8662 minor millets. These materials represent 128 countries, the majority of which are from Asia and Africa. This vast source of genetic diversity and evaluation data assembled at Patancheru, Andhra Pradesh is the basic material for all crop improvement activities including the application of biotechnology. Scientists in Mahaboobnagar and Nalgonda districts of Andhra Pradesh are fortunate in that they have easy access to the material and the germplasm database. The material is readily available for further evaluation and selection of parental lines for breeding and crop improvement in those and other districts of Andhra Pradesh.

ICRISAT has launched many germplasm collection missions in collaboration with international, regional, and national agencies. All the assembled germplasm is evaluated for 30 to 35 traits, during the rainy and postrainy seasons. Sources of resistance to biotic and abiotic stress factors
full potential and adaptation of germplasm, we conduct regional and multilocational evaluations at or near the place of origin or utilization. All the passport and evaluation data are computerized which fa

All of the assembled germplasm is conserved in the ICRISAT genebank, in both medium- and long-term cold storage chambers. To overcome loss of germplasm due to unforeseen reasons,
During rejuvenation and seed increase we follow appropriate pollination control such as selfing or controlled crossing. To minimize genetic drift, we use large populations of 100-200 plants per accession during each rejuvenation.

Scientists in National Agricultural Research Systems (NARS), regional and international organizations consider ICRISAT's genebank as a reliable source of germ-plasm and information. So far, we have distributed 1 119 212 samples, which includes 517 987 samples to scientists in ICRISAT, 315 030 in India, and 286 195 abroad. They include 470 507 sorghum, 120 492 pearl millet, 240 543 chickpea, 118 515 pigeonpea, 127 355 groundnut and 41 600 minor millets samples. This activity is probably one of ICRISAT's most valuable unique and long-term contributions that has considerable impact in NARS for sustainable crop improvement programs. The major users are scientists in NARS, regional and international organizations, universities, private and public sector organizations.

After evaluating the germplasm, several superior genotypes have been identified and released directly as varieties; 16 in sorghum, 10 in chickpea, 8 in pigeonpea, one in pearl millet and two each in groundnut and finger millet. Germplasm is also used as parents in crossing programs and several superior cultivars have resulted. A more imaginative and collaborative
be a fruitful program.

## Millets

Several species of small-seeded cereals, collectively referred to as millets, are produced in Andhra Pradesh. Of these, pearl millet (*Pennisetum glaucum*), foxtail millet (*Setaria italica*), and finger millet (*Eleusine coracana*) are probably the most important. The area sown to these crops in this state has declined over the past several decades and these are now minor crops, largely confined to marginal drylands. Major constraints to production of millets on these

In pearl millet the major problem has been downy mildew (caused by *Sclerospora graminicola*), especially on hybrids. Several downy mildew resistant pearl millet varieties and hybrids adapted to A.P. have been released in recent years. Open-pollinated varieties include ICTP 8203 (= MP 124; bold seeded, early, grain type released in 1988 that performs well under terminal drought stress), ICMV 155 (full season, dual-purpose grain + stover type released in 1991 as a higher yielding replacement for WC-C75), and ICMV 221 (released in 1993 as higher yielding replacement for the similar ICTP 8203). Hybrids include ICMH 451 (MH 179; full season dual-purpose type), Pusa 23
type with better downy mildew resistance than the similar BK 560), and ICMH 356 (released in 1993
mildew resistance is the major focus for research on pearl

The high-yielding foxtail millet variety Krishna Devaraya, bred at the Andhra Pradesh Agricultural University's Regional Agricultural Research station at Nandyal, has recently been released by the A.P. State Variety Release Committee.

Of seven areas identified by ICRISAT for our research on pearl millet, the two highest priority areas continue to be downy mildew and drought. Escape from terminal drought stress through early maturity, and improved
stress are the major areas of our crop improvement research to reduce losses to drought.
have an experimental composite population that matures in less than 65 days and has a yield potential of 1.5 to 2 t ha$^{-1}$. This composite is not competitive with longer duration cultivars in state and national trials, but should perform well compared to them when sown late or on shallow soils. Agronomic practices material need to be worked out. ICMV 221 was bred by selecting for terminal drought tolerance in the off-season drought nursery at ICRISAT Asia Center, and we plan to use this procedure to improve the drought tolerance of other open-pollinated varieties.

In downy mildew research our focus is on characterizing variability in the pathogen and using this information, and information on the inheritance of resistance, to facilitate efficient and effective deployment of resistance so that farmers are not forced to change hybrids every few years as the pathogen overcomes popular hybrids. Using marker-assisted backcrossing, we expect to have multiple downy mildew resistant versions of several popular hybrid seed parents available in 4 or 5 years. Meanwhile a broad range of new, productive, downy mildew resistant seed parents are available for use by pearl millet breeders in the public and private sectors.

ICRISAT, in collaboration with the Cambridge Laboratory (UK), has developed an RFLP-based genetic linkage map of pearl millet. The Cambridge Laboratory is developing a similar map for foxtail millet in collaboration with Chinese workers. The pearl millet map has been used to tag genes for host plant resistance to downy mildew, and a markers-assisted backcrossing program has been initiated to transfer some of these resistance genes into economically important male-sterile lines. Genes for early maturity have also been tagged. We hope to use one new mapping population to tag genes contributing to the ability to set and fill grain under terminal drought stress. Once available, such markers would greatly facilitate transfer of this trait to other genetic backgrounds. Thus biotechnological approaches have a major role in the future improvement of millets.

### Sorghum

Sorghum in Mahaboobnagar and Nalgonda Districts is a dual purpose crop producing both grain, for human consumption, and stover, for animal consumption. The sorghum cultivars grown by farmers are largely traditional. Improved cultivars are available but have not been widely adopted. Farmers' need for stover production for animal feed appears to be what maintains sorghum as a significant part of the cropping system in the drier areas of A.P.

Constraints to sorghum production in these areas include drought, grain molds, shoot fly, and stem borers. These are all difficult problems to deal with and to date no major impacts have reached farmers' fields, in spite of extensive research carried out over many years. Germplasm sources of drought resistance have been identified but the resistances have not been transferred to improved cultivars. Control of grain molds through the use of improved red grained cultivars that have higher levels of resistance than white grained sorghums is possible but these have not yet reached farmers' fields. We anticipate having improved cultivars with comparable levels of shoot fly resistance to the best local cultivars in the next five years. Partially improved breeding lines with resistance to stem borers have been produced but these are not sufficiently high yielding to find favor with farmers.

Because of their complexity and the failure of conventional techniques to generate solutions to these problems, they are now being considered as potential candidates for biotechnological approaches. Molecular markers are being sought for component traits of drought resistance (particularly stay green) and for shoot fly resistance. The possibility of transformation of sorghum with Bt genes to control stem borers is being actively investigated.

And the possibility of using antifungal proteins in white sorghum grains as a component of grain mold resistance is also under investigation.

## Groundnut

Andhra Pradesh is the largest groundnut producing state in India. Out of 2.4 million ha of groundnut in A.P., about 1.5 million ha is grown in the Rayalaseema region. This region receives low rainfall and experiences frequent mid-season drought. Southern Telangana region (which also includes Nalgonda and Mahaboobnagar districts) also has similar rainfall patterns besides having shallow soils. Except for North-Central and Northern Telangana regions, where rains are excessive for groundnut, drought (both mid-season and end-of-season) is the major constraint to groundnut production in the rainy season in A.P. Other important constraints to groundnut production include foliar diseases (rust, late leaf spot), root rots, nematodes, insect pests (jassid, leafminer, whitegrub), and nutritional deficiencies (sulfur, iron).

In spite of many varietal releases in the state, TMV 2, a mass selected population from a local race, released in 1940, still remains a leading cultivar in the rainy season. Lately, facilities have been strengthened to produce seed of newly released improved cultivars in enough quantity so that the old cultivars could be replaced at a faster pace.

The Andhra Pradesh Agricultural University (APAU) and Indian Council of Agricultural Research
a collaborative project entitled, "APAU-ICRISAT Collaborative Research in Groundnut Breeding" has been in operation. This project has given a further impetus to the on-going research program of the state.

The APAU has released many cultivars suitable for different agroecological regions of A.P. These improved cultivars include Kadiri 2, Kadiri 3 (Robut 33-1), Kadiri 71-1, K 134, TPT 1, TPT 2, and TPT 3. TPT 2 and TPT 3 are resistant/tolerant to Kalahasti Malady caused by nematodes, and K 134 is tolerant to bud necrosis, rust, and late leafspot. A package of cultivation practices has also been developed.

The ICAR-ICRISAT collaboration has led to the release of many cultivars which are suitable for cultivation in the state. These include ICGS 76, ICG(FDRS) 10, and ICGV 86590 for cultivation in the rainy season, and ICGS 11 and ICGS 44 for cultivation in the postrainy season with irrigation. ICG(FDRS) 10 and ICGV 86590 are resistant to foliar diseases. An improved package of cultivation formulated by ICRISAT showed a 20% pod yield advantage over common cultivation practises in on-farm trials conducted by the Andhra Pradesh State 'Cooperative Oilseeds Growers' Federation.

The APAU-ICRISAT collaborative project in groundnut breeding has given a stimulus to groundnut improvement activities in the state. Since 1992, promising new material identified included:

- ICGV 86347 and ICGV 86300, for the entire state.
- ICGV 86699, a dual purpose variety, for Anantapur district
- ICG(FDRS) 4, a foliar diseases resistant variety for Prakasam district.

In the near future, these varieties may be released in A.P. For Anantapur district in the Rayalaseema region, which is perhaps the largest groundnut growing district in the world (0.75 million ha), a separate collaborative breeding program has been started to develop short-duration drought tolerant/resistant varieties. A convergent crossing program involving six groundnut genotypes is in progress
selection in the district in the 1995 rainy season.

Groundnut research objectives for the rainy season crop are not likely to change in the near future. Incorporation of resistance/tolerance to drought and foliar diseases in a good agronomic background will continue to remain the most important objective.

Due to lack of availability of seed of improved cultivars in sufficient quantities, the scope for impact in the rainy season crop of groundnut in the near future is limited. The possibility of impact in the postrainy season irrigated crop is much better as farmers are opting for new cultivars because of the high yields realized with irrigation.

If genetic markers are identified for drought resistance/ tolerance or associated traits, the crop improvement efforts in the state will be boosted. Higher levels of resistance to late leafspot and resistance to groundnut leafminer are other areas where biotechnology, including interspecific hybridization could play a significant role.

**Chickpea**

In the harsh SAT areas, which include A.P., the major production constraints of chickpea are considered to be drought, *Helicoverpa* pod borer, wilt and dry root rot and therefore research on these has had high priority. These constraints not only affect productivity, but also affect production area, and through these parameters the total production of chickpea. Madhya Pradesh is the largest producer of chickpea
producing 1.57 million tons of seed at 700 kg $ha^{-1}$. Andhra Pradesh grows only 0.08 million ha, and produces 0.04 million tons of seed at 565 kg $ha^{-1}$. For Mahaboobnagar district, corresponding figures are 3,000 ha, and 700 tons of seed at 269 kg $ha^{-1}$; and for Nalgonda 550 ha, and 156 tons at 284 kg $ha^{-1}$.

To alleviate the effects of drought stress, advancing the sowing date by one month can increase the yield by 25%. Under low-fertility conditions
yield of 1.5 t $ha^{-1}$ was recorded when the sowing date was advanced by 1.5 months in 1989. Reducing the crop duration of chickpea can also allow it to escape terminal drought stress. The earliest flowering and maturing chickpea cultivar is ICCV 2, a kabuli cultivar. It was

released in A.P. in 1989 as Swetha. It combines the traits of extra-short duration, resistance to fusarium wilt and relatively large seed size. Apart from escape, drought resistant chickpea lines have also been identified. Screening of germplasm accessions under irrigated and non-irrigated conditions enabled initial identification of two drought resistant lines, ICC 495 and ICC 10448, and more drought resistant lines have been identified since.

Among sources of resistance to *Helicoverpa* pod borer, the best resistant line, ICC 506, showed a mean of 8.6% pod borer damage and yielded an average of 1.2 t $ha^{-1}$ while cultivar Annigeri suffered 29.9% damage and gave a yield of 1.0 t $ha^{-1}$. The national chickpea research program in India has identified more resistant lines. The line ICCL 86111 combines resistance to *Helicoverpa* and fusarium wilt. The latest achievement in pod borer resistance breeding is the development of a line that resembles Annigeri but is resistant to *Helicoverpa* and soil-borne diseases. On-farm testing of this line is to take place during the 1994/95 chickpea cropping season.

Fusarium wilt is probably the most widespread disease of chickpea. Dry root rot, caused by *Rhizoctonia bataticola* is a soil-borne disease as serious as fusarium wilt, but less well studied. However, sources of resistance have been identified. Collaborative efforts between Indian NARS and ICRISAT have led to the release in A.P. of three varieties resistant to fusarium wilt:

- ICCV 2 (Swetha): an extra-short duration kabuli cultivar, that carries resistance genes against fusarium wilt.

- ICCC 37 (Kranthi): a short duration desi cultivar, also resistant to fusarium wilt, that produces dhal of excellent quality.

- ICCV 10 (Bharati): a short-medium duration desi cultivar with wide adaptation, fusarium wilt resistance, and of high yield potential.

Over the years, there has been a regular and sustainable exchange between ICRISAT and A.P. scientists of chickpea seed carrying various useful traits.

Breeding

Germplasm enhancement will need to receive more emphasis in this context. The breeding of extra-short duration chickpea is anticipated to bear fruit rapidly. In all this we seek close collaboration with NARS scientists

Mutation breeding as characteristics may contribute even more than it has done so far. Application of biotechnology to chickpea has good prospects. The main practical interests for breeders are probably, at the moment, interspecific crossing, genome mapping, and marker studies. This work has been initiated and ICRISAT collaborates for that purpose with mentor institutions such as John Innes Center, Norwich, U.K. But, indeed, it has only been initiated, and much remains to be done.

For instance markers for root characteristics, resistance factors and quantitative traits can greatly enhance the effectiveness of chickpea improvement and close collaboration with and support from advanced laboratories will undoubtedly stimulate progress.

**Pigeonpea**

Traditionally, pigeonpea cropping systems in Andhra Pradesh have involved quantitative short-day, temperature-sensitive, duration to maturity, usually intercropped or mixed with a variety of crops, mainly cereals. At ICRISAT, and in collaboration with the Indian NARS, much progress has been made in developing cultivars with resistance to the two major pigeonpea diseases in A.P., fusarium wilt and sterility mosaic disease. For example, the medium-duration cultivar ICPL 87119, with resistance to both of these diseases, is now undergoing on-farm tests on Vertisols in Adilabad district to stimulate adoption.

Another major constraint of pigeonpea is insect pest damage, particularly that of *Helicoverpa* pod borer. The medium-duration cultivar ICPL 332 has been released for cultivation in A.P. on the basis of its better tolerance to this pest than other cultivars. There are also other sources of *Helicoverpa* resistance in the medium-duration group, the entire germplasm collection having been screened for this trait, but resistance levels are relatively low, especially as pest pressure increases. Thus, to enhance host plant resistance to *Helicoverpa* the current most promising options would rely on biotechnological approaches - introgressing genes from related wild species and insertion of *Bacillus thuringiensis* genes. However, long-term viability of pigeonpea as a crop will depend on development of reliable integrated pest management (IPM) strategies. Currently, ICRISAT is involved in IPM studies with pigeonpea in the Tandur area.

In the medium-duration group, cultivar ICPL 85063 has proved productive for postrainy season cultivation of pigeonpea in Guntur, Prakasam and Nalgonda districts. Yields of up to 4 t $ha^{-1}$ have been realized on farmers' fields.

From the late 1970s, however, ICRISAT has been giving increasing emphasis to development of pigeonpea of shorter duration than the traditionally intercropped cultivars and landraces commonly grown in A.P. The purpose was to develop plant types of higher productivity per unit area and time and of wider adaptability and flexibility (e.g. for use in sole cropping). An example of an outcome of this endeavor was the release of ICPL 87, a short-duration cultivar (120 days duration at Patancheru), for peninsular India. This genotype has particularly good rationability and, if soil moisture remains available (e.g. through moderate irrigation), can yield over 5 t $ha^{-1}$ from three harvests within 9 months.

We have gone further in developing shorter-duration genotypes, with lines now available that can yield over 2 t $ha^{-1}$ within 90 days. In a collaborative exercise with APAU, we have conducted extensive multilocation testing of these extra-short duration genotypes across A.P. The genotypes ICPL 84031, ICPL 88034 and ICPL 35010 were identified for on-farm testing in northern Telangana (Warangal and adjoining districts including Nalgonda), for rainfed and irrigated systems, sole and double cropping and in Alfisols and Vertisols. This testing was initiated in 1994 and prospects for impact appear promising.

Another important breakthrough in pigeonpea research has been development of hybrids. The first pigeonpea hybrid, the short-duration ICPH 8, was released for cultivation in India in 1991. However, hybrid technology is so far based on genetic male sterility, which makes the hybrid seed production process cumbersome and costly. These problems can be alleviated by development of cytoplasmic male sterility systems, where progress is now evident.

In the various endeavors of screening pigeonpea for resistances to biotic and abiotic stresses it is apparent that many sources of reasonable levels of resistance reside in the related wild species. Many of these are non-crossable with cultivated pigeonpea by conventional means and therefore biotechnological approaches to introgress the required resistances into cultivated pigeonpea are required.

## 10.3 RESOURCE MANAGEMENT

Resource management research at ICRISAT has been aimed at developing strategies for sustainable food production in rainfed areas of the semi-arid tropics, with particular emphasis on improving the nutritional status and general economic well-being of low-income peoples. This research has been conducted in three broad research domains - factors of the physical environment, biological factors and socioeconomic factors - and has been oriented towards providing SAT farmers with low-cost sustainable technologies.

Early resource management research efforts at ICRISAT concentrated on developing "Vertisol technology" - techniques to alleviate waterlogging effects and allow cropping in the rainy season and to maximize soil water conservation for postrainy season cropping. These techniques have found application in various "watershed schemes" in India and elsewhere. However, recent research emphasis has been on developing a better understanding of the physical and biological processes involved in optimum soil management to support sustainable agricultural production - including studies on nutrient cycling, soil water-holding characteristics, soil structure in relation to erosion, soil biota, etc.

Other studies focussed on sustainability of SAT cropping systems include agroclimatic analysis, crop establishment, behaviour of cropping systems in terms of biotic and abiotic processes, crop rotation effects, and agroforestry. Socioeconomic research has covered characterization of production environments, measurement of sustainability, village level studies, impact assessment and research evaluation, and market analysis.

Each of the above resource management topics obviously have relevance to the target regions and subject matter of this Workshop, but we will only elaborate on two of them. One refers to village level studies (VLS), where ICRISAT's initial experience has been comprehensively documented in a book by T S Walker and J G Ryan (the current Director General

of ICRISAT) entitled "Village and Household Economics
One of the benchmark village sites of the study was Aurepalle in Mahaboobnagar district, A.P. A comprehensive database and analysis for this village alone provides a valuable reference point for agricultural development in the region.

Another aspect of likely interest to this Workshop is a recent initiative relating biotechnological approaches to integrated nutrient management in cropping systems. This stems from ICRISAT studies showing the role of root exudates in releasing sparingly available soil phosphorus for plant uptake. In March,
consider the feasibility of molecular and cellular biological manipulations to enhance the effects of these exudates, and even to transfer their ability to be produced across
A global project on genetic manipulation of phosphorus acquisition by crop plants is consequently under formulation.

## 10.4 CONCLUSION

This paper only briefly summarizes aspects of ICRISAT's research of potential relevance to Nalgonda and Mahaboobnagar districts of A P. Those interested
on any aspect are encouraged to request the relevant detailed literature from ICRISAT. There is indeed a wealth of information, published
agricultural development in areas adjacent to ICRISAT's headquarters. Further, ICRISAT would welcome entering into further collaborative activities with adjacent NARS and external organizations wishing to contribute to agricultural development in A P. We are sure that there are many synergies to be gained.