GENETIC RESOURCES: COLLECTION, CATALOGING, AND CONSERVATION OF PEARL MILLET

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Presented at the All India Coordinated Millets Improvement Project Workshop at Mahatma Phule Agricultural University, Rahuri (Dist. Ahmednagar) Maharashtra State

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A. Introduction:

As you may now know, I am at ICRISAT for a period of one year as temporary Leader of the Genetic Resources Unit in place of Dr. M.H. Mengesha, permanent Leader, who is at Iowa State University, Ames, Iowa, U.S.A., for a one year sabbatical. Having been coordinator of a Regional Research Project on Genetic Resources at Ames, Iowa for 27 years I retired in October, 1983. At Ames, we maintain more than 150 crop species, most of which are adapted to the temperate climatic zones but pearl millet is not among them. We had several minor millets, however, like proso millet, foxtail millet, and barnyard millet. Nonetheless, the principles of germplasm collection, maintenance, preservation, cataloging and distribution are quite similar for most field crops.

Germplasm is the basic raw material needed in any crop improvement program, so it becomes necessary to establish and develop germplasm banks in suitable locations to receive, preserve, evaluate, and distribute this valuable raw material. There is overwhelming evidence in the literature to indicate that genetic diversity is rapidly eroding in many areas of the world and in some places it is lost entirely. To meet the challenge of assembling this diversity

before it disappears forever, National and International programs have developed during the past 15 to 40 years which cooperated to form a global network of germplasm conservation centers and crop improvement activities to help provide the increasing amount of food required to feed the growing world population and to find ways of alleviating stress to populations suffering from extended periods of drouth.

ICRISAT is one of 13 global centers established under auspices of the Consultative Group on International Agricultural Research (CGIAR). It is dedicated to those stated objectives and in order that its crop improvement programs have a continual supply of raw materials, it devotes a certain amount of resources to the Genetic Resources Unit for the collection and preservation of crop diversity. Since ICRISAT serves the semi-arid tropics, (SAT), its mandate crops are pearl millet, sorghum, groundnut, chickpea, and pigeonpea. Therefore, collections of landraces and wild species of these crops are made in countries included in the SAT, like parts of India, the countries of eastern, western, and southern Africa, Asia, South America, and other similar parts of the world.

B. Collections:

1. Direct Exploration:

Since its establishment in 1979, the Genetic Resources Unit launched a number of pearl millet germplasm collection missions in Africa, India, and other countries of Asia. We refer to this as "direct exploration" because our crops scientists visit the countries to make the collections in the field. It is important that proper protocol be followed when making advance arrangements such as

preliminary contacts with counterpart scientists to determine the feasibility of an exploration and then presenting the exploration proposal to the Ministry of Agriculture, or other appropriate authority, as a collaborative mission and requesting permission to enter the country for performing the work. It is the usual procedure for the country visited to provide a counterpart scientist, and a vehicle with driver. ICRISAT pays certain transportation and per diem expenses agreed upon and when the collection is completed, the seed is divided, with the greatest portion remaining in the country of collection, a portion to IBPGR and the rest to ICRISAT. Thus, it becomes a truly cooperative venture that mutually benefits both ICRISAT and the country visited. Of course, once the seed is secure in the ICRISAT collection it is always freely available to the country in which collected as well as to any other country in the world.

2. Seed Exchanges:

Wherever possible, gaps in the world collection of pearl millet are being filled by correspondence and exchange with other gene banks and crop improvement scientists around the world. This has been an effective means of obtaining diverse germplasm for the ICRISAT collection but this is considered a supplement to direct explorations and not a substitute for them.

3. Countries where Collections were made:

So far, we have collected only once in several areas of diversity. However, it is usually necessary to collect areas more than once in order to capture diversity missed the first time because of climatic conditions, because of entering the area at a different

stage of maturity, or because of entering new areas not covered the first time.

a) India:

Table I shows the locations of collections made in India by GRU scientists and state or national collaborators between 1977 and 1984. Prior arrangements for collecting in India are made with the Indian Council of Agricultural Research (ICAR), and the actual collecting is accomplished jointly with an ICRISAT scientist and a National or University scientist exploring together. It is hoped that in the future more exploration in India can be conducted jointly by the National Bureau of Plant Genetic Resources and ICRISAT.

Figures 1 and 2 are an example of collection routes followed on two missions in India. It is evident that Mahatrashtra was covered quite thoroughly (Figure 1) as was a rather small portion of southern Andhra Pradesh (Figure 2).

(b) Other Countries:

Even before the establishment of the Genetic Resources Unit in 1979, ICRISAT's Botanists made some direct explorations for pearl millet in African and Asian countries. Exchanges were also made at that time with various gene banks, both national and international, in various countries as well as with plant breeders. Table II summarizes the accessions of pearl millet germplasm assembled since the beginning of ICRISAT in 1972 and includes accessions assembled before and after the establishment of the Genetic Resources Unit in 1979. The table also shows all the countries from which pearl millet germplasm was

assembled either by direct exploration or by seed exchange as well as the total number of accessions from each.

It is obvious that some countries are well represented by germplasm collection while others are not. Two possible reasons for this are (1) that certain countries grow very little pearl millet and therefore one cannot expect much diversity or (2) that the country may grow considerable pearl millet but collections have not been made as yet. Such areas receive high priority when planning future plant exploration missions.

It is significant to note the total number of accessions, assembled in India is 11,137 and of that number, 7,600 accessions were donated by millet scientists. Of course, this represents excellent cooperation by millet scientists in India through National and State Programs.

The overall total of pearl millet accessions now in our collection is 17,081 accessions and represents germplasm from 39 countries. While this is a large collection with much genetic diversity, more collecting still needs to be made to assemble as much diversity as possible to help fill the needs of pearl millet scientists and to place it in the ICRISAT collection before more genetic erosion occurs.

c. Wild Species:

In addition to making collections of cultivated pearl millet, Pennisetum americanum (L.) Leeke, just described, it is also highly important to collect wild species related to pearl millet. Wild

species have persisted throughout the ages without the hand of man to plant, cultivate, and protect them from disease and insect pests, so they are most likely to carry resistance genes to various pests, as well as having some other possible desirable traits like drouth resistance. If such genes or traits can be transferred to cultivated pearl millet, it is understandable that quality and resistance attributes can be improved, thus providing better yields at less cost to the growers.

The greatest barrier to transferring these valuable genes and traits to the cultivated species is that of incompatibility, which means that attempted crosses between the species will either abort or produce sterile seed that will not reproduce. Research directed toward hybridizing the two species is underway in the GRU program with some degree of success. Table III lists the names of the wild species in our collection and the number of accessions of each. It also shows that three possible interspecific hybrids have been produced. This work will be continued in the future.

C. Preservation of Collections:

After seed collections are made it is necessary to make seed increases using techniques that will prevent outcrossing among accessions but yet allow for interpollination within accessions of cross pollinated crops in order to retain the genetic diversity of the original collection.

Once the seed increases are made, they must be stored under proper conditions of temperature and humidity to prolong viability as long as possible. These conditions will be discussed later.

1. Operational Flow Chart:

Figure 3 is an operational flow chart developed by GRU staff showing the flow of seed from collection to distribution. According to the chart, all foreign introductions are first grown in an isolated quarantine area where they are monitored by quarantine scientists throughout the growing period for possible symptoms of disease or insects. If none are found, they are released to ICRISAT, harvested and prepared for storage. Infected accessions are appropriately handled.

After release to ICRISAT, the accessions are grown the following season for further seed increase, evaluation, and classification. After that increase they are numbered with ICRISAT numbers, registered and entered into the computer and the seed is placed in cold storage and held for eventual distribution of small samples to scientists for further evaluation, research, and utilization.

2. Types of Cold Stora e:

There are three types of cold storage conditions for seed, each having its specific purpose. They are short term storage, medium term storage and long term storage.

Short term storage rooms are maintained at 15 degrees to 20 degrees C. with minimum amount of humidity control. Short term storage is usually meant for holding seed temporarily for 6 months or less. Seed handling and preparation for medium or long term storage are often done under these conditions.

Medium term storage rooms are usually maintained at 4 degrees C. with humidity controlled at between 20 and 30%. This is the most common type of storage condition used by gene banks for maintenance of active germplasm collections because the temperature is low enough to preserve viability and yet high enough to permit workers, with some protective clothing, to spend long periods of time in the room for filling seed requests or for various maintenance needs of the seed collections. The temperature is also low enough to minimize or completely prevent insect activity.

Long term storage rooms are maintained at -20 degrees C. and are intended for storing seed many years without disturbing it. Usually the seed stored in long term storage is dried to a moisture content of 7 to 9%, placed in metal containers and sealed. With such protection against humidity changes plus the very low temperature, seed will remain viable for many years longer than under medium term storage conditions.

Thus, it will not require rejuvenation as frequently and serves as a backup to the active collections. This is a real advantage because in germplasm preservation one tries to rejuvenate the seed as infrequently as possible to minimize exposure of the accessions to unavoidable genetic drift which usually occurs, in varying amounts,

during any rejuvenation regardless of amount of care given.

Long term storage conditions are used for holding base collections of germplasm and for a backup to active collections.

3. Seed Increases:

Seed is grown for increase, classification, evaluation and characterization in two separate plantings in order that the seed increase plots are not disturbed while making evaluations, characterizations, and classifications.

In the seed increase plots, pollination control of pearl millet accessions is accomplished by use of the so-called multiple-head bagging method to prevent outcrossing. Two to three heads are covered with a single bag and most of the heads in each plot are covered in this way. Such protection will prevent outcrossing but at the same time will permit interpollination of the heads bagged together. After harvest, the seed from all the bagged heads within an accession is mixed before placing into storage. Seed increase plots usually contain accessions grown for the first time (after quarantine) as well as plantings of older accessions that were either low in seed supply or those that tested less than 85% in germination tests.

D. Characterization, Evaluation and Classification Plantings:

Each year 3000 to 4000 accessions are grown for seed increase and for characterization/evaluation. Evaluations have been made on a total of 20 descriptors and this data are placed into the computer along with passport data for documentation and speedy retrieval.

Table IV shows the number of accessions evaluated and documented as of 1984. It also shows the number of accessions of specific genetic stocks available.

Table V shows the range of variation of 18 characteristics in pearl millet. For example, during the rainy season, the earliest flowering accession in the collection requires only 33 days from planting to 50% flowering while the longest one requires 140 days. The shortest plant in the collection is only 35 cm tall while the tallest is 475 cm.

Tables VI and VII show preliminary results of cooperative evaluation/screening performed by ICRISAT millet scientists and Biochemistry. It is emphasized that this represents preliminary or promising data only and should be regarded as such. However, it does provide an indication of sources of certain traits.

Table VIII provides a list of traits evaluated in the evaluation and characterization plots which are documented in the computer. This list can be helpful to pearl millet scientists to inform them of the array of evaluated traits now available to them. The pearl millet descriptor list developed by ICRISAT and IBPGR as referenced in Table VIII may also be helpful because it defines and describes the range of values assigned to each trait. Reprints are available from GRU.

E. How to Request Seed from ICRISAT's GRU:

The characterization/evaluation traits and passport data for each accession are in the computer and can be easily and quickly retrieved. Therefore, I wish to emphasize that any scientist who needs germplasm

material from ICRISAT's Genetic Resources Unit needs only to write to the Leader, GRU (either to me now or to Dr. Mengesha when he returns) and specify the traits and the limits or parameters of each trait and we can send seed samples of accessions that most nearly fit the requirements.

It is important for me to mention that seed catalogues which list and describe the entire collection are not generally available now nor are they likely to be in the future. A single computer printout with all available information would likely be at least 16 to 20 centimeters thick. However, computer printouts for small segments that concern your specific needs can be made available.

F.Acknowledgements:

I wish to express my grateful acknowledgement to members of the GRU staff who have helped with the preparation of this document; Mr. C. Rajagopal Reddy for assistance with preparation and updating the tables and charts and information on the pearl millet collection, Mr. Prasada Rao for advice and reviewing the document; Mr. S.G. Jaiswal for typing the text and Ms. Shobha for typing the tables; and other staff who helped in any way, including Drs. M.H. Mengesha and S. Appa Rao for previous reports. A word of appreciation is also extended to the Pearl Millet Program and to Biochemistry for use of their information on pearl millet germplasm evaluation.

Table I. Collections of Pearl millet made in India between 1977 and 1984

State	Date of collection	No. of samples
Andhra Pradesh	Jan'77	70
	Oct'80	133
Orissa	Jan'77	28
Rajasthan	Sept'77	366
	Sept./Oct'78	13
Tamil Nadu	April'78	200
	June'80	7
Maharashtra	Sept./Oct'78	437
	Sept./Oct'79	12
	Oct./Nov'81	122
Karnataka	Oct./Nov'81	5
	Nov'80	22
	March'80	1
Gujarat	Sept./Oct'78	448
Madhya Pradesh	Sept./Oct'78	23
	Dec'78	24
Uttar Pradesh	Oct'79	462
Punjab	Oct'83	204
Eastern Ghats	Oct'84	113
TOTAL		2690

Table II. Pearl millet germplasm accessions assembled at ICRISAT Center through Direct Exploration and Exchange** (December. 1984)

Country	Total	Country	Total
AFRICA		**AFRICA** (cont'd)	
Benin	40	Zambia	81
Botswana	45	Zimbabwe	175
Burkina Faso	387		
Cameroun	191	Source unknown	11
Cent. Afr. Rep.	58		
Chad	62	**ASIA**	
Congo	3		
Ethiopia	1	India	11137*
Gambia	13	Korea	1
Ghana	246	Lebanon	71
Kenya	69	Pakistan	8
Malawi	245	Turkey	1
Mali	1039	Yeman Arab Rep.	17
Mauritania	1	USSR	12
Mozambique	28		
Niger	1032	**EUROPE**	
Nigeria	710		
Senegal	360	United Kingdom	27
Somalia	3	West Germany	1
South Africa	84		
Sudan	559	**THE AMERICAS**	
Tanzania	138		
Togo	75	Brazil	1
Uganda	48	Mexico	7
		USA	90
		AUSTRALIA	4
Total :		39 Countries	17081

* Includes 7600 accessions donated by millet scientists in India.
** Exchange material represents accessions from Rockefeller Foundation, ICRISAT/IBPGR/ORSTOM and the USA.

Pearl millet germplasm accessions distributed by ICRISAT 1972 through 1984

Number of samples			No. of recipient
ICRISAT	INDIA	ABROAD	Countries
17,259	14,259	15,192	60

Table III. Wild species of Pennisetum and some possible interspecific hybrids maintained at ICRISAT Center.

Species	No. of accessions
Pennisetum cenchroides	1
P. clandestinum	1
P. divisum	1
P. hohenackeri	6
P. macrostachyum	1
P. mecrorum	1
P. mezianum (2n, 4n)	2
P. mollissimum	1
P. orientale	2
P. pedicellatum	8
P. polystachyon sub sp. polystachyon	5
P polystachyon sub sp. setosum	3
P. purpureum	8
P. ruppelii	1
P. schweinfurthii	4
P. setaceum	1
P. squamulatum	1
P. villosum	1
P. violaceum	15
Cenchrus ciliaris	5
Total	68

Possible interspecific hybrids

Hybrid Napier x P. squamulatum

P. typhoides x P. purpureum
(Hybrid Napier)

P. orientale x P. typhoides

Table IV. ICRISAT progress with Pearl millet germplasm 1978-1984 (December)

Items	1978	1984
ACCESSIONS		
Assembled	6796	17081
Evaluated	5962	16968
Documented*	340	7379
Distributed		
- in ICRISAT	1482	17259
- in India	7945	14259
- abroad	5407	15192
Wild species (accessions)	11(17)	20(68)
Countries represented	15	39
Collection missions	3	15
GENETIC STOCKS		
Disease resistant**	-	27
Drought resistant**	-	7
Glossy	-	8
Sweet stalk	-	4
Male sterile lines	9	17
Dwarfs	1	14
Chlorophyll mutants	-	11
Other characters	-	7

* Entered in computer
** Promising lines

Table V. Range of Variation in Pearl millet in Rainy Season Planting

Character	Minimum	Maximum
Days to 50% flowering	33	140
Plant Height (cm)	35	475
Peduncle exsertion (cm)	-21	+30
Midrib color	White	Purple
Spike length (cm)	5	165
Spike thickness (mm)	11	64.5
Glume color	Straw	Dark purple
Glume covering	Exposed	Complete covered
Grain color	White	Dark purple
Bristle length (mm)	2	60
1000 grain weight (g)	2.54	19.32
Tillering (No.)	1	210
Stem sugar content (%)	4.94	19.74
Grain No./spike	379	3337
Stem thickness (mm)	2.8	15
Leaf (No.)	6	25
Leaf length (cm)	25	120
Leaf width (mm)	11	78

Table VI. Numbers of confirmed sources of disease resistances identified by the Millet Pathology subprogram, through 1984

Disease	Number screened		Total No. resistant sources identified
	Accessions of the GRU	Breeding lines/ populations	
Downy mildew	2753	7076	124
Ergot	2800	7800	24 (+60 lines developed)*
Smut	1800	8200	34 (+150 lines developed)*
Rust	2562	507	86

* Inbreds and sib bulks

(From : Assessment of ICRISAT Research on pearl millet diseases and future plans. S.B. King, Principal Pearl millet Pathologist. Presentation at an Institute level Seminar on April 2, 1985 at ICRISAT Center).

Table VII. Pearl millet germplasm evaluation/screening results

Screened for	No. of accessions screened	No. of promising lines	Identified and described in collaboration with
1. Insect Resistance			
Mythimna spp.	100	8	Millet Entomology*
Shootfly	424	45	"
Aphids	100	14	"
Shoot Bugs	100	8	"
Thrips	29	3	"
Spider mites	324	31	"
2. Disease Resistance			
Downy mildew	2753	124	Millet Pathology*
Ergot	2800	24	"
Smut	1800	34	"
Rust	2562	86	"
3. Drought Resistance	509	2	"
4. Other characters			
Protein	3523	100	Biochemistry*
Sugar analysis	8	4	"
Male sterility	16968	5	Genetic Resources
Glossy leaf	16968	8	"
Dwarf lines	15388	6	"
Genetic stocks	15388	692	"
Viable chlorophyll mutants	16968	11	"

*Courtesy of Pearl millet subprograms as indicated.

Table VIII. List of Traits evaluated in Pearl millet Germplasm during Rainy Season

1. Days to 50% flowering
2. Plant height (cm)
3. No. of total tillers
4. No. of productive tillers
5. Nodal tillers*
6. Spike exsertion (cm)
7. Synchrony of spike maturity*
8. Spike length (cm)
9. Spike thickness (mm)
10. Spike shape*
11. Spike density*
12. Bristle length (mm)
13. Grain shape*
14. Grain color*
15. 1000 grain weight (gm)
16. Endosperm texture*
17. Photoperiod sensitivity*
18. Green fodder yield potential*
19. Grain yield potential*
20. Overall plant aspect*

*See Descriptors for Pearl millet, IBPGR/ICRISAT, 1981 Publication No. AGP:IBPGR/80/31, September, 1981.

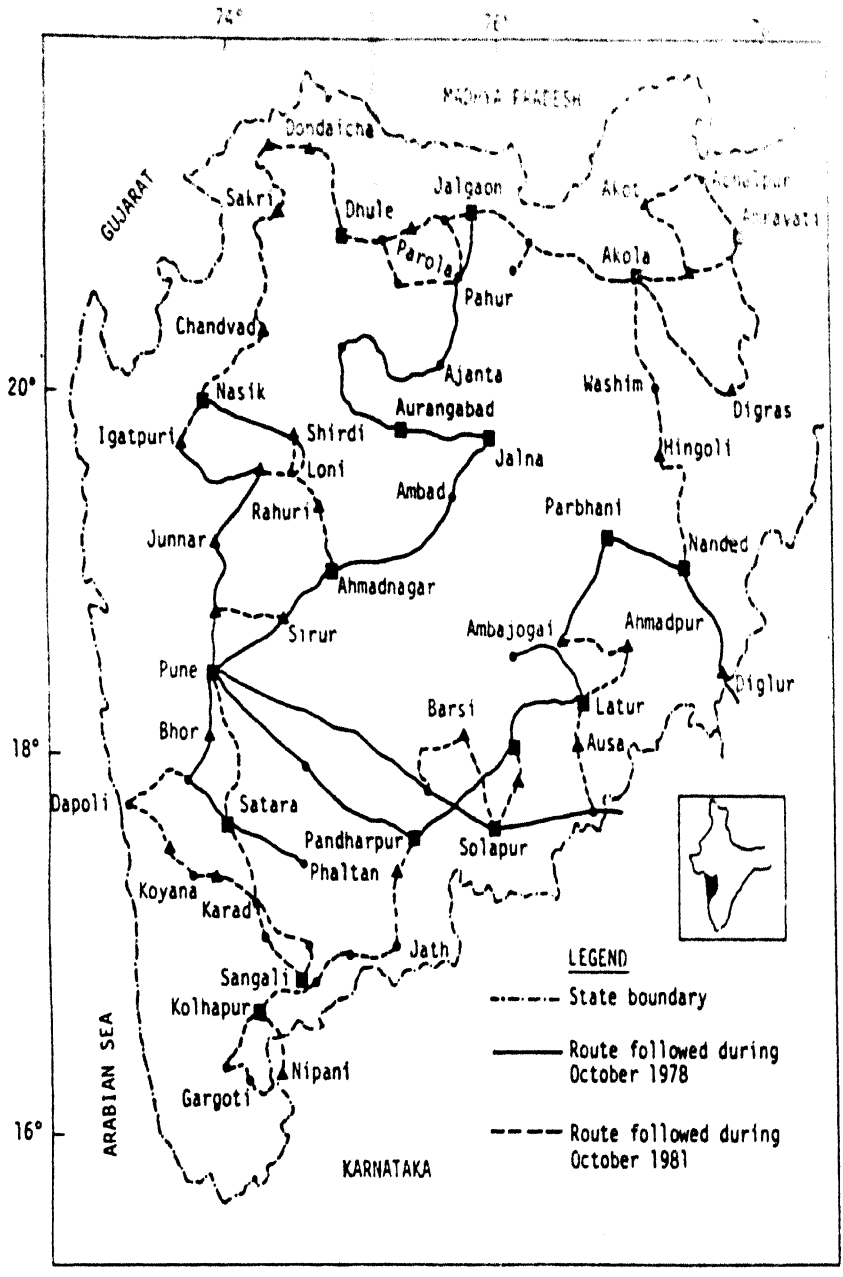

Figure 1: Route followed and areas covered during 1978 and 1981 collection missions in Maharashtra.

(From: V. Ramanatha Rao and C. Rajagopal Reddy. Collection of Groundnut and Pearl Millet germplasm in Maharashtra, India. Genetic Resources Progress Report-39. ICRISAT).

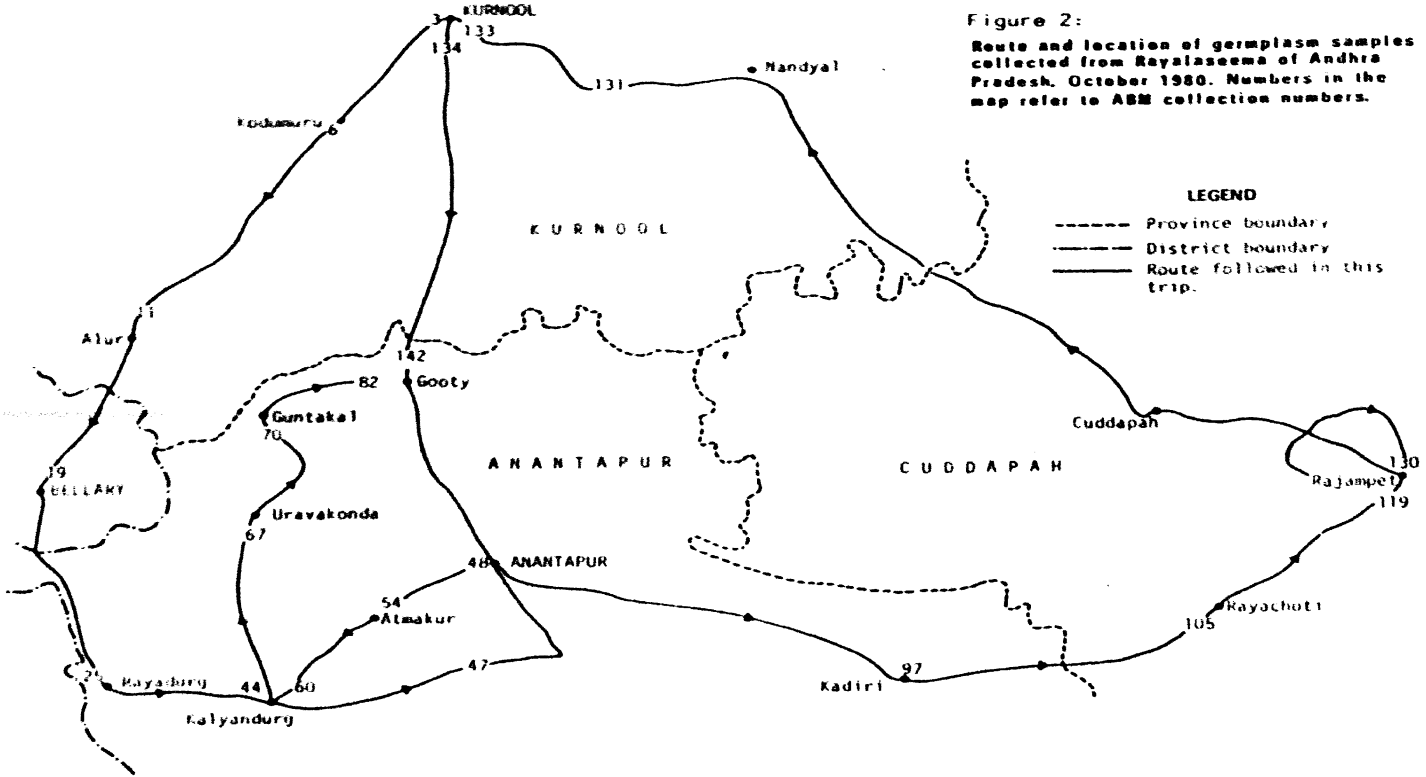

Figure 2:

Route and location of germplasm samples collected from Rayalaseema of Andhra Pradesh, October 1980. Numbers in the map refer to ABM collection numbers.

(From: S. Appa Rao, F.R. Bidinger and V. Mahalakshmi. Pearl Millet germplasm collection from Rayalaseema Region of Andhra Pradesh, India. Progress Report Genetic Resources 26, October, 1980. ICRISAT).

Figure 3: GENETIC RESOURCES UNIT ICRISAT
OPERATIONAL FLOW CHART