ICRISAT

INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS

ANNUAL REPORT 1974-75

ICRISAT Annual Report 1974-75

International Crops Research Institute for the Semi-Arid Tropics
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Hyderabad 500016 (A.P.), India

C O N T E N T S

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ICRISAT Personnel — March 31, 1975

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J S Kanwar, Ph D , associate director
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R Vaidyanathan, purchase and supplies officer
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N Rajamani, New Delhi liaison representative

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P Lawrence, Ph D , assistant plant breeder (sorghum)
J C Davies, Ph D , entomologist
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Research Associates

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K V Ramiah, Ph D (sorghum)
D S Murthy, Ph D (sorghum)
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A K Auckland, Ph D , plant breeder (chickpea)
L J G van der Maesen, Ph D , botanist
A R Sheldrake, Ph D , physiologist
Y L Nene, Ph D , pathologist
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K B Singh, Ph D , associate plant breeder (chickpea)

Research Associates

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K B Saxena, Ph D (pigeonpea)
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R P S Pundir, M Sc (Ag) (germ plasm)
A N Murthy, Ph D (germ plasm)
S S Lateef, Ph D (entomology)
A Narayanan, Ph D (physiology)
Miss Swaraj Kumari Ph D (physiology)
N P Saxena, Ph D (physiology)
M P Haware, Ph D (pathology)
M V Reddy, Ph D (pathology)

Farming, Water and Crop Management Systems

B A Krantz, Ph D , agronomist
J Kampen, Ph D agricultural engineer (soil and water management)
S K Sharma, B A senior research technician

Research Associates

S N Nigam, Ph D (agronomy)
S V R Shetty, Ph D (agronomy)
J Hari Krishna, M Sc (soil and water management)
R C Sachan, M Tech (Agr Eng), (soil and water management)
P N Sharma, M Tech (soil and water management)
Piara Singh Ph D (soil science)
Sardar Singh, Ph D (soil science)
K L Sahrawat, Ph D (soil science)
Harbans Lal, M Tech (farm machinery and power)

Farm Development and Operations

E W Nunn, B S (Agr Eng), agricultural engineer
B K Sharma, B Sc (Ag Eng), farm services supervisor
D S Bisht, B Sc (Ag & AH) (Hons), farm operations supervisor
D N Sharma, B Sc (Ag Eng & Tech), farm development supervisor

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M von Oppen, Ph D , economist
H P Binswanger, Ph D , economist
N S Jodha, Ph D , associate economist
H S Sandhu, Ph D , assistant economist
K V Subrahmanyam Ph D , research associate
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Training

A S Murthy Ph D , associate training officer

Biochemistry and Nutrition Laboratory

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S P Yadav, Ph D , research associate

Information Services

K R Kern, Ph D , information officer
E G Lawrence, B S , assistant information officer
S M Sinha, N Dip (Com Art), Artist
H S Duggal, Photographer

Library

T C Jain M Lib Sci , Librarian

Plant Quarantine

T B Lal, M Sc , plant quarantine officer

Physical Plant Development and Services

A D Leach Ph D , engineer
F J Bonhage, construction supervisor
Sudhir Rakhra B E , engineering associate (civil)
M A Makhija B E (Civil), Civil engineer
H C Tewari, M S A , assistant engineer
V Ramachandran, B E , engineering associate (electrical)
D Subramanian, B E (Elec) electrical engineer
V Lakshmanan executive assistant

Special Projects

C M Pattanayak, Ph D , plant breeder (Upper Volta)

About this Report

This second annual report of the International Crops Research Institute for the Semi-Arid Tropics has been printed for readers the world over The report gives research highlights of scientific investigations on cereal improvement, pulse improvement, farming systems, and economics for the period April 1974 to March 1975

Detailed reporting of the extensive activities of ICRISAT's many research support units is not possible in this publication The Director's introduction lists some of the important contributions made by these units to our research program

In this publication, data are reported in the metric system The unit "t/ha" refers to metric tons (1,000-kg) per hectare and "q/ha" denotes quintals (100-kg) per hectare

The Hindi word 'kharif" refers to the monsoon season, usually occurring from June through September or October The Hindi word "rabi" is used for the dry, post-monsoon season, generally occurring from October through January

ICRISAT receives support from the Consultative Group on International Agricultural Research Responsibility for all aspects of this publication rests with the International Crops Research Institute for the Semi-Arid Tropics Mention of particular insecticides, fungicides, herbicides or other chemicals or mention of individual varieties does not necessarily imply endorsement by this Institute

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Director's Introduction

April 1974 through March 1975 was a year of rapid development in ICRISAT operations. Additions of international scientists and supporting staff expanded and deepened the research programs already underway and launched vigorous efforts in other programs. It was a year of continuing emphasis to develop resources and facilities at the research site with activity ranging from the architectural engineering of the eventual campus to construction of roads, bore wells, and lakes (tanks, they are called in India), and preparation of land for precision farming operations required in research plots.

The research programs themselves — in Crop Improvement and Farming Systems — command the principal focus of our work. And the bulk of this annual report deals with highlights from research activities in this second full year of the broad based efforts.

However, a wide range of contributing and supporting activities accompany the research work. These activities, too, were enlarged and extended during the year.

Center Development

Persistent inflation and uncertain economic conditions in India during the report year complicated the processes of planning and contracting for development of permanent facilities at the farm. Temporary facilities were provided both at the farm and in existing buildings in the city of Hyderabad. Several structures in the evacuated village of Manmool were fitted as field laboratories for entomologists, pathologists, physiologists, and plant breeders. A large private dwelling in the Banjara Hills of Hyderabad was rented to provide offices for scientists and space for the protein research laboratory, library, and information services. Additional private housing facilities for international and support staffs were provided through the rental of privately owned facilities in the city Eventual plans call for housing to accommodate about a fourth of the key institute personnel at the research site

Two issuances of tender documents to prospective Indian contractors were necessary during the year before contracts were let By March 1975 contracts had been awarded for the civil engineering plumbing electrical and air conditioning work Construction was underway by the end of the report year

Prof C F Bentley, chairman of ICRISAT's Governing Board and the Institute's director, Dr R W Cummings receive India's Prime Minister, Smt Indira Gandhi The Prime Minister was guest of honor at ICRISAT's foundation stone ceremonies at ICRISAT Center on January 11, 1975

Dr R W Cummings explains the new ICRISAT Center to the Prime Minister of India, Smt Indira Gandhi The Center, now being constructed 25 kilometers from Hyderabad, is expected to be finished in 1977

Prime Minister Indira Gandhi laid the foundation stone for the permanent buildings on January 11 1975 About 3 000 guests took part in those formal ceremonies

Land Development

ICRISAT headquarters land resource base is 1 394 ha Before its assignment to the institute parts of the area were cropped by farmers in two small villages, others parts were grazed still other parts were virtually abandoned due to erosion or unproductive vestiges of former shallow tanks Transformation of these areas to research sites calls for rapid and precise operations to shape land areas reclaim abandoned

Dr Cummings, following Indian custom, breaks the traditional coconut signifying the start of construction of the ICRISAT Center

land, develop water storage and access facilities and establish roadways

Continuing operations in the report year emphasized road development — including some 40 culvert or bridge installations to accommodate vital access roads without affecting drainage patterns, development of two service reservoirs with a total water storage capacity of 4 ha m land shaping and other precision development on almost 70 ha of future research blocks and reclamation of 60 ha in the basin of a former tank

Farming operations utilize both the speed and power of modern machinery and the traditional animal and human power of the region At times of peak field activity, as many as 600 daily workers scatter over the fields A trained corps of local operators for ICRISAT's fleet of tractors dozers, land planes and field equipment assures efficient work when those machines are needed More than 10,000 hours of tractor operation were logged in 1974 75 A large shipment of surplus equipment from U S military depots in Europe contributed to the growing inventory of power machinery to back the urgent needs of ICRISAT development

Library

From a beginning just a few months before the current year, the ICRISAT library had assembled, trained and activated a staff of six persons to de velop and carry out this vital support service By the end of March 1975, the library collection had grown to 2,688 books, 1,045 bound volumes of periodicals, 344 periodical subscriptions, plus 124 photocopies and 187 microforms The library circulated 1,662 documents to ICRISAT scientists It had borrowed 187 documents from other Hyderabad libraries and 15 from libraries outside to meet needs of the researchers

The ICRISAT library emphasizes collections related to the primary research thrusts of the in stitute Its staff has assumed responsibility for significant bibliographic work in the same areas It has brought out an important bibliography of the Indian scientific literature on sorghum millet, and pulses covering the years 1969 to 1973

Information Services

Quarterly issues of *At ICRISAT* continued through the report year This 4 page information piece goes to more than 2,000 persons throughout the world who have indicated an in terest in the programs and progress of ICRISAT Each issue reports on research highlights from the principal research programs, along with ac counts of activities in personnel, program de velopment, and relationships with the institute's publics around the world

Even before its formal inauguration, ICRISAT attracted visitors to the research site, and the numbers grow These contacts bring important interactions of ICRISAT personnel with the peo- ple we serve As we show them our work and dis- cuss our plans, we learn from the special expertise and orientation of our visitors — whether they are Indian cultivators on an extension study tour or leading research scholars from the great institutions of the world. During the report year, our visitors' book showed a total of 553 distinguished visitors of which 138 were from foreign countries.

Training and Outreach

Four young Nigerian extension workers inaugurated the training program of ICRISAT in this year. They arrived in June 1974 to undertake six months of study and training with research and operations personnel. They worked in all phases of our crop improvement and farming work.

In addition to their studies with ICRISAT scientists — including lecture and discussion sessions similar to university instruction — the trainees carried out many practicums in the field. They learned field operations from ground preparation through harvesting by doing the operations themselves. By the end of their study period, the young men were trained to undertake field studies and demonstrations that could help diffuse the ideas and materials of ICRISAT and other research centers of the world.

While the principal training was centered at ICRISAT, the trainees were given important additional learning opportunities through other resource institutions in the immediate area. For example, they studied Indian extension organization and operations. They also worked with Indian and international scientists in programs associated with the Andhra Pradesh Agricultural University, Rajendranagar, the state extension training center, and several All-India coordinated programs in agriculture.

By the end of the report year, international staff was on board to further develop training, which is regarded as of parallel importance to the development of ideas and materials from the fields and laboratories.

During this period international workshops were held on farming systems and grain legumes.

A cooperative program on sorghum and

millets improvement with the various countries in the Savannah Zone of West Africa was initiated during the year, with the support from the United Nations Development Program Active discussions were also initiated with scientists and officials in various other countries of the semi-arid tropics in which ICRISAT's program might be expected to have relevance

This report presents a summary of progress in the institute's research program for the year ending March 31, 1975

Common Names of ICRISAT's Four Crops

Language	*Sorghum vulgare*	*Pennisetum typhoides*	*Cicer arietinum*	*Cajanus Cajan*
English	Sorghum, Durra, Milo,Shallu, Kafir Corn, Egyptian Corn, Great Millet, Indian Millet	Pearl Millet Bulrush Millet Cattail Millet Spiked Millet	Chickpea, Bengal Gram, Gram, Egyptian pea, Spanish pea, Chestnut bean, Chick, Caravance	Pigeonpea Red Gram
French	Sorgho	Petit Mil, Millet Mil a Chandelles	Pois Chiche	Pois Cajan
Spanish	Sorgo Zahina	Milo Perla Millo	Garbanzo Garavance	Gandul
Hindi	Jowar	Bajra	Chana	Arhar, Tur

CROP IMPROVEMENT

THE CEREALS

- Sorghum
- Pearl Millet

THE PULSES

- Pigeonpea
- Chickpea

THE CEREALS

Sorghum Improvement

The ICRISAT Sorghum Improvement program will have its main contact and cooperative activity with plant breeders in the semi-arid tropics through our international testing project. We hope to gather elite material from other plant breeders, from our own program, and from the world germplasm; we will distribute it widely for trials or nurseries for testing over many locations. We will include lines that carry useful characters, such as good resistance to pests or diseases, which may be helpful as parents in other breeders' programs.

The second stage of the program aims to tackle urgent problems: resistances to pests, resistances to grain mould, and resistance to the witchweed, *Striga*, and improving grain quality. We are carrying out projects with regional application, namely: West African sorghums, East African sorghums, and high altitude sorghums.

The third aspect of the program involves plant physiological aids in creating more efficient plants and the development and exploitation of composite populations under recurrent selection. Here, there is much to learn about the best methodology, while at the same time improving the populations and withdrawing lines from them for elite testing. The evaluation of lines out of populations in the normal course of applying recurrent selection procedures will be an important source of material for the international testing project.

International Testing

The kharif, or monsoon, season of 1974 brought the beginning of our systematic efforts to improve plant breeding materials and to test performance of many thousands of sorghum lines. In earlier seasons we gathered useful preliminary information and grew out and increased quantities of many important lines in breeding collections.

We were not yet organized to test any materials outside the research site at Patancheru, and hence, all materials were tested in five environments at the site: Red soil—high fertility; red soil—low fertility; black soil—high fertility; black soil—low fertility; shoot-fly-infested—low fertility.

In 1974, the testing program included the following lines grown in the five environments:

Season	Lines Tested		
	Elite	From Populations	
Summer 1974	50	—	
Kharif 1974	2,592	2,528	
Rabi 1974-75	244	1,407	
Total	3,336	3,935	7,271

In addition to goals for improving yield and evident grain quality characteristics, our breeding program aims to develop lines that have pest resistance, grain mould resistance, improved nutritional quality, and adaptability to other sorghum-growing areas of the semi-arid tropics. We can report some progress in pursuit of these goals in 1974-75. (Tables 1 and 2 are the best results.)

Pest Resistance

Three major pests threaten sorghum in India: shoot-fly, *Atherigona;* stem borer, *Chilo;* and midge, *Contarinia*. Cooperating with ICRISAT entomologists, we involved 5,120 lines in work on pest resistance in kharif 1974. Using early planted susceptible spreader rows and fishmeal as an attractant, we gained shoot-fly incidence of 90 percent.

Table 1. Characteristics of best entries from sorghum elite trials, kharif 1974. Hyderabad 1974.

Entry	Days to flower	Height cm	Shoot-fly rating	Grain yield q/ha	100-grain weight g	Quality rating	Grain mould rating
57 - 538	52	170	2 6	68 0	2 80	1	3
72 - 004	61	120	2 3	65 3	3 01	2	3
72 - 018	59	130	2 5	62 3	2 46	2	3
67 - 171	63	240	2 6	60 3	3 01	4	1
52 - 053	54	190	2 6	60 0	2 55	2	3
52 - 710	61	160	2 5	59 8	2 47	6	4
72 - 96	59	120	2 0	59 8	2 52	2	3
57 - 204	61	150	3 3	58 8	2 86	6	3
62 - 357	57	160	2 6	57 5	3 00	6	3
57 - 197	61	160	2 6	56 9	2 36	4	4
67 - 245	59	150	1 6	56 8	2 74	5	2
62 - 512	63	160	2 0	56 8	2 13	6	3
52 - 196	54	180	2 3	56 2	2 48	1	2
62 - 280	52	160	2 3	55 7	2 69	6	3
52 - 240	59	150	2 3	54 8	2 88	6	3
57 - 620	57	120	3 0	54 8	2 80	6	3
52 - 188	54	150	2 6	54 4	2 68	4	4
62 - 541	61	210	2 0	52 2		5	3
52 - 529	63	140	2 5	52 2	2 63	6	3
47 - 1014	60	170	2 0	50 4	2 90	6	2
42 - 1048	51	110	2 5	50 1	2 97	6	
57 - 709	63	180	2 0	49 8	3 09	6	3
62 - 417	57	110	2 0	49 8	2 30	1	3
42 - 1149	61	130	3 0	46 8	2 47	6	·
52 - 598	59	170	2 3	45 6	2 32	4	3
42 - 1075	61	170	2 0	44 3	2 37	4	
57 - 516	63	230	3 0	44 3	2 88	6	2
42 - 1108	63	150	3 0	42 7	2 49	5	
42 - 1053	61	165	2 5	42 6	2 16	5	
42 - 1011	62	120	2 5	42 3	2 39	4	
57 - 181	57	180	2 3	40 4	2 88	6	2
42 - 1049	57	135	2 5	40 4	2 25	4	
42 - 1117	66	125	3 0	37 4	2 48	6	
67 - 246	55	150	2 0	34 8	2 23	4	3
42 - 1019	61	125	2 3	30 0	2 01	4	

Ratings: Shoot-fly and grain mould characteristics were scored on a scale of 1 (good) to 4 (bad)
Grain quality rating key is 1 red grain, 2 mixed, 3 white with subcoat, 4 chalky white, 5 yellow; and 6 pearly white

Table 2. Performance of sorghums in elite trials, rabi 1974. Hyderabad 1974.					
Entry	Pedigree	Yield q/ha	Days to anthesis	Plant height cm	100-seed weight g
2	Pioneer 22 E (hybrid)	55 4	66	140	2 89
12	IS 173	47 0	62	145	3 28
18	IS 6380	44 7	62	140	3 27
41	EC 64734	42 4	75	110	2 42
53	SA 5875 · 6 · 1 B	42 4	64	120	2 43
49	IS 3817	41 3	60	185	2 41
68	EC 64612	40 7	69	110	2 40
	CSH 1 (hybrid)	40 6	68	140	2 82
4	Pioneer 24 E (hybrid)	40 4	68	170	3 00
1	Pioneer 21 E (hybrid)	40 1	64	135	3 36
34	EC 65066	39 8	58	120	2 43
63	Diallel 1071	39 5	66	150	2 28
79	Diallel 870	39 5	68	130	1 91
58	Diallel 642	39 0	68	150	2 18
80	Diallel 603	38 7	65	130	2 78
57	Diallel 464	38 7	70	140	1 84
23	IS 858	38 4	68	135	2 22
17	IS 3401	37 8	69	150	3 30
27	IS 2215	37 2	68	120	2 07
13	IS 184	36 1	70	160	2 38
52	IS 8088	35 8	69	105	2 22
3	Pioneer 23 E (hybrid)	35 2	64	140	3 36
37	EC 64145	34 6	68	115	2 44
77	Diallel 642	34 1	70	130	2 78
32	EC 64735	34 1	69	75	2 45
64	Diallel 1207	34 1	70	160	2 07
62	Diallel 883	33 8	70	115	2 38
28	NES 311	33 2	68	100	2 27
35	EC 64601	32 0	68	120	1 80
48	EC 16144	32 0	64	135	2 51
72	Diallel 1215	32 0	72	118	1 83
65	Diallel 1235	31 8	72	130	1 69
26	IS 2927	31 8	64	120	2 01
59	Diallel 828	31 5	71	135	2 12
60	Diallel 881	31 2	72	135	2 23
70	Diallel 7017	31 2	61	110	2 60
71	Diallel 870	30 9	68	125	1 80
21	IS 2214	30 3	70	115	1 76
24	NES 2824	30 0	69	120	2 31
29	NES 3141	30 0	67	100	2 26
66	Diallel 1251	30 0	71	110	2 47
56	Diallel 464	29 7	69	150	2 41
15	IS 2042	29 2	77	115	2 53
51	IS 8189	28 9	64	95	2 06

Table 2 – *continued*

Entry	Pedigree	Yield q/ha	Days to anthesis	Plant height cm	100-seed weight g
43	EC 65063	28 6	68	115	2 88
67	Diallel 1322	28 3	77	120	2 15
39	EC 65352	28 3	70	90	2 29
73	Diallel 35	28 3	75	145	2 08
16	IS 2918	28 0	57	125	2 56
33	EC 64830	28 0	62	100	1 79
74	EC 65337	28 0	64	120	3 90
69	Diallel 7500	27 4	69	100	1 86
45	EC 65267	27 4	68	140	3 20
40	EC 65352	27 4	70	95	2 13
36	EC 64650	27 4	69	135	2 28
78	Diallel 642	27 1	76	115	2 37
75	Diallel 7195	26 8	68	115	1 96
47	EC 65562	26 8	74	95	2 89
61	Diallel 870	26 8	70	120	1 96
31	EC 64619	26 3	70	85	2 31
22 or 25	IS 2223	25 3	68	100	1 76
8	E 303	25 1	70	165	1 96
42	EC 64650	23 4	70	125	3 12
11	IS 165	23 1	83	100	2 24
6	CSV 148	21 9	83	95	2 24
46	EC 65276	21 9	72	120	2 60
38	EC 65556	20 8	74	110	1 48
5	CSV 302	20 5	76	105	3 04
19	Maldandi	20 2	95	235	3 78
14	CSV 370	19 9	75	135	2 37
10	CS 3541	19 6	75	105	2 82
76	Diallel 1322	18 5	80	115	1 91
7	E 302	18 1	74	155	1 97
9	DMS 652	17 9	61	175	1 70
20	Swarna	11 0	75	125	3 93
	Mean	32 0	69 2	126 2	2 44
	L S D	9 6			
	C V	15%			

Planted Sept 19 1974

Screening disclosed 354 entries which may have primary resistance These entries, along with another 878 entries that included a collection of resistant lines from Coimbatore, were grown again in the rabi season Some showed excellent resistance We identified 49 lines that show primary resistance to shoot-fly, 17 of the lines combined good agronomic characters and the pearly white grains preferred by Indian consumers

Dr. H. Doggett, leader of the Cereal Improvement Program assessing promising lines of sorghum.

No artificial infestation of stem borer was introduced. However, the 354 shoot-fly resistant lines also showed a low level of stem borer attack. Low levels of midge infestation did not let us assess resistance reported for 70 lines included in these observations.

Breeding efforts were begun with regard to these three pests: 41 shoot-fly resistant lines were emasculated and pollinated with bulked pollen from an ms_7 source; 13 lines with apparent resistance to stem borer were emasculated and pollinated with pollen from an ms_3 source; 7 of the lines reported to be resistant to midge were crossed with bulked pollen carrying ms_3. Our aim is to develop a composite population that will carry resistance to all three of these sorghum pests.

Mould Resistance

Many short term sorghums attain consistent yields and make better use of available rainfall than is true with indigenous photoperiod sensitive longterm types. However, the grains do not withstand weathering when they ripen during the rains. We are approaching this problem from two aspects: First, collaborating with plant pathologists, we are seeking better resistance to grain mould; second, we are seeking to transfer the large papery glumes on some cultivars as a means of providing a complete cover for the grain.

Three main categories of mould problems exist: (1) Head blights, such as *Curvularia* and *Fusarium* that may attack early and blight the head; (2) Saprophytic fungi, such as *Colletotrichum, Penicillium, Helminthosporium, Phoma* and *Olpitrichum*, which result in deterioration of the developing grain; (3) Superficial moulds, which develop on the surface of the ripe grains standing in the fields.

Earliness and Mould Resistance

A crossing program was commenced to incorporate both earliness and mould resistance into an adapted genetic background. Some 300 crosses were made in the rabi season, and further crosses were made in the Coimbatore summer planting. Among materials in the crossing program were: 9 IS conversion lines; 6 good adapted parent lines from the All-India Coordinated Program; 3 lines that had performed well in West Africa; 1 from Ethiopia; mould-tolerant lines CS 3541 and 2219B. In the Coimbatore planting, crosses involved: early sorghums from Kenya; zera zeras; yellow pericarp types; 2KX selections from East Africa and others. Seed was obtained also from a mould-tolerant composite developed by Dr. S. B. King in West Africa.

Large Glumes

We have selected a number of large glume parents from the germplasm collection which have tan colored glumes and thresh easily. Most of these lines are tall, photosensitive types, and we are attempting to transfer this large glume character to high yielding, adapted lines by making single and double crosses: 192 crosses were made in 1974:

Large glume	x	early	80
Large glume	x	adapted	78
Large glume	x	mould-tolerant	34

Striga Resistance

The parasitic weed *Striga* is a major threat to sorghum. Fortunately, some sorghum plants show resistance or tolerance. The most useful form of resistance is likely to be low stimulant production, since there is little prospect of such resistance breaking down without rendering the parasite vulnerable to stimulant production by non-host plants. A *Striga*-resistant composite has been developed by Dr. S. B. King in Nigeria — he screened resistant types from the world collection, crossed to ms_7 and then backcrossed to other resistant types. This composite was received and grown at ICRISAT in rabi 1974-75. A wide range of elite lines was chosen from the international nursery and used as female parents to make 120 crosses with the composite.

Seeds of two species of *Striga* in India are available for the work at ICRISAT: *Striga asiatica*, from Gujarat, Karnataka, Maharashtra and Patancheru, the site of the ICRISAT research station; *Striga densiflora*, from Gujarat.

Another line of attack against *Striga* involves compounds that cause the seeds to germinate when there is no acceptable host plant present on which the parasite may develop. In cooperation with the International Development Research Center in Great Britain, this approach is under study at ICRISAT. Synthetic analogues of the compound strigol were tested on the black and red soils of the research site. Dr. Gerald Roseberry of Sussex University is cooperating in this work.

Grain Quality

We do not know enough yet about grain quality in sorghum. We can observe that sorghum eaters have preferences: white, cream or yellow grain — free from water-soluble pigments; plump, free threshing grains of clean appearance — thin pericarp and low fiber content; hard, largely corneous endosperm — which makes the best flour and is resistant to weevils in storage.

We have little definitive knowledge about cooking quality, flavor characteristics, or gross digestibility of the final food products. Until some tests requiring only small amounts of grain have been devised to estimate these factors, selection for improved quality will remain difficult. A research center that would concentrate on these consumption qualities would make a large contribution to sorghum breeders everywhere.

Researchers in the United States have developed measures of protein percentage and amino acid balance. Simple tests are available to help the breeder deal with the protein characteristics of lines he works with. While these cryptic quality characters do not account for consumer preference, they represent important considerations.

High Lysine Types

In the rabi season 1973-74 we grew out a number of progeny from crosses and backcrosses of high lysine types (IS 11167 & IS 11758) onto the Purdue populations. The Ethiopian lines with high lysine gene produce a ripe seed that is shrivelled, has a small endosperm, and is opaque on the light box. Since the opaque endosperm is often soft, floury and of unsuitable quality for the consumer, we decided to concentrate on chemical screening instead of screening for opaqueness on the light box.

All samples were initially screened using the biuret method for protein and the UDY method for basic amino acids. Selected lines were then screened using the micro-kjeldahl and UDY methods.

The biuret method permits us to make more rapid tests — one person can make about 80 estimates per day, compared to about 25 by the micro-kjeldahl method. The micro-kjeldahl is more accurate, according to our tests, but we find the biuret satisfactory to eliminate low lysine grains; those with higher biuret scores are then tested by micro-kjeldahl.

Our biochemistry section screened 1,651 entries grown in 1973-74 rabi from crosses involving Purdue populations crossed with Ethiopian high lysine lines. That screening showed 64 entries with protein content of 10 percent or above (UDY values of 30.0 or above). A total of 158 entries selected with UDY values of 28.0 and above were planted in kharif 1974. However, rains in October — late in the growing season — degraded grains and chemical tests were not reliable. Selection was thus made on the basis of grain and agronomic characters, and those chosen were planted in rabi 1974-75. Chemical analyses (biuret plus UDY) of these grains (Table 3) confirmed the results obtained from the 1973-74 rabi.

Fifty-four rows and 128 plants taken from the upper end of the original distribution, with UDY values of 28.0 or better, were put through a second screening using micro-kjeldahl plus UDY. We selected 20 entries from 12 rows, all with plump grains and some with corneous outer endosperm shell. Four have red pericarp, but the other 16 are white throughout.

Plump Opague Grains

Three hundred heads with plump opaque grains were selected from the rabi 1973-74 planting. All were planted in kharif 1974, but only 140 germinated and grew through to harvest. In-

Table 3. Results of selection based on screening with biuret plus UDY procedures in populations containing Ethiopian high-lysine gene. Hyderabad 1975.

UDY value of head selections (class)	No. of progeny rows two generations later		Percent of rows with high UDY	No. of heads		Percent of heads with high UDY
	UDY > 30	UDY < 30		UDY > 30	UDY < 30	
28-29	6	59	9.2	9	192	4.5
30-31	21	58	26.6	42	466	8.3
32-33	12	29	29.3	27	182	12.9
34-35	5	8	38.5	12	56	17.6
36-37	7	6	53.8	37	62	37.4

tercrosses were made between individual plants, and selfs and crosses were planted in rabi 1974-75 Twenty-eight rows and 39 plants were selected from this group, based on screening with biuret plus UDY, followed by micro-kjeldahl plus UDY Results are set out in Table 4

In the rabi 1973-74 plantings of the Purdue crosses, we made a series of selections for plants of good agronomic type from rows which showed high lysine segregates About 2,250 were screened by biuret plus UDY, with 78 chosen for micro-kjeldahl plus UDY procedures We expect most of that group to be confirmed as high lysine

Screening on the light box was relatively more efficient than the chemical screening, since progenies from 20 percent of the original opaque selections gave plump high lysine grains with a subcoat, compared with 7 6 percent from the selections made by buiret plus UDY screening However, there would seem to be a greater probability of obtaining desirable endosperm types from the non-opaques identified chemically

Other materials with high lysine possibilities have also had some attention 23 mutants from Purdue, 205 entries of the BG collection from Ethiopia—collected in the same area as IS 11167 and IS 11758, and a tall, late highland Ethiopian variety, RY 49, alleged to taste like wheat

Most of the protein levels determined in this phase of our work fall between 6 4 and 9 0 percent Five were found between 9 1 and 10 1 We are almost certainly choosing low prolamine types

We emphasize that the high lysine target we seek in sorghum is near the average lysine level of wheat and below that of rice Our improvement strategy emphasizes total grain yield as a more promising means of increasing the total amount of protein available to the consumer than through dramatic changes in the protein level in the grain

West African Sorghums

Some materials from programs in West Africa seem to hold promise in the conditions of the rabi season in India Three of twenty such entries tested at Hyderabad in rabi 1974-75 yielded favorably compared to Indian varieties The 50 q/ha level of CSH1 was equalled by lines 9290, 7047 and Pickett 3

Hybrids have been made with selections from bulk Y composite used to pollinate kafinam A Two of the parents were good maintainers, and they were backcrossed to develop female parents for new hybrids

Selected plants from the West African composite populations (bulk Y and WABC) have been crossed with parents carrying such qualities as pest resistance, good grain, earliness or early seedling vigor A total of 1,516 selections were taken from these crosses for screening for resistances and for photoperiod sensitivity Such materials need good resistance to pests and to *Striga* for desirable performance in West Africa and also for the rabi season in India

Seeds of these lines were taken to Upper Volta, a location to which much of this work will be gradually shifted

East African Sorghums

Useful levels of disease resistance and tolerance of shoot-fly and *Striga* are carried in elite materials from East African programs The materials have done well in South America and Thailand, so we are introducing photoperiod insensitivity into this material to extend its area of adaption

We made reselections from two groups of material planted in September 1974 388 reselections from 584 coarse grain elite lines and 509 reselections from 359 lines in the 2KX cross series We also planted F_1's of 421 crosses between Serere coarse grained lines and the photoperiod insensitive Purdue population PP3 and 30 similar crosses of a Nebraska population pollinated by the 2KX material

A group of 474 2KX selections, with some photoperiod insensitivity were screened in progeny rows in two replications We took reselections and harvested 132 entries as derived lines Forty-eight entries from the East African material were put into 1975 trials for South America, Thailand, and the Philippines

Table 4. Protein values (biuret plus UDY and Microkjeldahl plus UDY) with plump, well-filled grains originating from opaque kernels chosen two generations previously. Hyderabad 1975.

Row No.	Plant no.	Biuret protein	UDY value	Mkj protein	UDY value
79751	4	5.7	43.0	7.6	30.0
79755	1	8.3	33.0	9.4	29.5
79767	2	5.7	43.5	7.4	30.0
79767	3	7.3	33.0	8.3	28.5
79775	5	7.0	34.0	8.0	29.0
79869	5	5.7	38.0	7.1	28.0
79873	1	5.3	38.0	6.8	28.5
79873	2	5.7	35.0	6.7	28.0
79889	3	7.0	32.0	8.2	28.0
79895	5	6.7	36.5	8.1	30.0
80027	4	6.3	37.5	8.1	29.0
80027	5	6.3	35.0	7.5	28.5
80059	3	7.3	30.0	7.7	28.0
80071	3	6.7	39.5	8.6	28.0
80071	4	6.7	38.5	8.1	31.5
80075	1	8.0	30.5	8.3	29.0
80075	5	6.0	44.0	7.0	35.0
80079	1	6.3	40.5	7.5	32.5
80083	1	6.0	36.0	7.1	29.5
80091	2	6.0	36.5	7.4	29.0
80091	4	6.7	36.0	7.5	28.0
80091	5	6.0	39.0	7.5	28.5
80103	4	8.0	34.0	8.9	28.0
80107	1	5.3	42.0	6.5	32.0
80107	3	6.7	31.0	6.5	32.0
80107	4	6.7	30.0	6.7	29.0
80107	5	5.7	38.0	6.4	34.0
80113	3	6.3	32.0	7.2	28.0
80175	5	5.7	40.0	7.2	30.0
80263	2	6.3	34.0	7.3	28.5
80263	3	6.5	32.0	6.8	30.5
80263	4	6.3	36.0	6.8	29.5
80315	3	7.2	34.5	8.2	28.0
80323	2	8.3	30.0	10.1	31.0
80369	1	8.3	31.0	9.3	29.0
80499	3	7.3	34.0	8.6	28.0
80505	1	7.7	30.5	8.5	29.0
80517	1	5.7	42.0	7.4	29.5
80551	4	7.0	33.5	8.4	28.5

High Altitude Sorghums

Ethiopia and Mexico will serve as base locations for the main work on high altitude sorghums A useful input can come from ICRISAT in Hyderabad, however A high altitude population was recombined at Hyderabad and Nebraska population 10 reputed to have cold tolerance, was also random mated in isolation We made a planting at Ootacamund in the Nilgiri Hills where 30 S_1's from each of these populations were planted

Sixteen elite lines that performed well in Ethiopian multi location trials were crossed to seven entries adapted to various low altitude locations These have been planted at Coimbatore Twenty five entries from the Ethiopian germplasm collection, which were selected for grain quality, yield, and other agronomic characters, have been crossed to the seven low altitude lines

All these entries, along with CIMMYT, are being grown at Ootacamund to assess cold tolerance and high altitude performance

Advanced Composite Populations

This year we have worked with 13 advance composite populations Two were yield tested in Kharif 1974, and the summarized results are given in tables 5 and 6 The advanced populations will be improved for overall performance including maximizing grain yields, improving grain quality and food value, reducing susceptibility to diseases, pests, and *Striga*, and reducing harvest losses from lodging, head moulds, and grain weathering Table 7 presents the details of the populations and in the sections that follow we highlight the year s activities with each of the populations

Fast Lane R and B

In the kharif of 1974 we selected half sib progeny rows 554 from the R population and 326 from B We put these entries into the summer 1975 nursery and some 10 lines from each will be recombined to start the next cycle The S_1 lines were grown in two replicates each in both the red and black soils of the research site Table 5 gives the progress We aim to develop two populations that will be well adapted to the rabi environment, and we aim to do it rapidly We will apply high selection pressure and recombine from only a few lines at the start of each new cycle These populations could be the basis for composites, synthetics or varietal hybrids available for release to farmers

Table 5. Characteristics of two advanced composites. Hyderabad 1974-75.

Population	No of lines	Days to 50% flower	Plant height cm	Yield — q/ha Red soil fertile	Black soil fertile	Average
Fast lane R population						
Entire	277	81	124	52 50	48 32	50 39
Selected	10	80	121	64 87	51 15	58 01
Selection differential		1%	2%	24%	6%	15%
Fast lane B population						
Entire	196	77	116	47 43	52 41	50 07
Selected	10	79	129	61 53	63 15	62 34
Selection differential		−3%	−11%	30%	21%	25%

Table 6. Mean performance of lines tested — entire population — and of lines used for combining the population. Hyderabad 1975.

Population	No. of lines	Days to 50% flower	Plant height cm	Shoot-fly score	Yield — q/ha				100-grain	Grain quality score
					Red soils		Black soils			
					fertile	unfertile	fertile	unfertile		
US/R Population										
Entire population	1852	56	127	2.58	40.7	596	38.7	482	2.55	1.90
Selected population	104	54	146	2.58	51.2	680	51.5	538	2.75	2.26
US/B Population										
Entire population	749	57	111	2.55	43.6	614	33.4	875	2.37	1.85
Selected population	68	57	110	2.42	48.9	816	45.6	1032	2.48	2.58

Shoot-fly score: percentage of dead hearts — 1. none; 2. 25%; 3. 25 to 81%; 4. 82% and over.

Grain quality score: 1 red; 2. red and white segregation; 3. sub-coat; 4. chalky white; 5. yellow endosperm; 6. white corneous.

Table 7. Summary of information on selected factors of advanced populations of sorghum improvement program of ICRISAT. Hyderabad 1975.

Name of population	Components of population	Source of material —origin	Source of male sterility	Proposed selection method
Fast lane R	18NP1, 10NP3, 4NP4, 4NP5, 11NP8 lines	Nebraska	ms_3	S_1 rabi testing
Fast lane B	15NP2, 15NP6 lines	Nebraska	ms_3	S_1 rabi testing
US/R	23PP1, 31PP3, 32PP5, 8NP4, 4NP5, 6NP8 lines	Purdue and Nebraska	ms_3	S_2 testing
US/B	25PP2, 23PP6, 9NP2, 11NP4, lines	Purdue and Nebraska	ms_3	S_2 testing
Serere elite	64RS5DX, 19RS5D x CSF, 26RS1 x VGC, 81 Hyd RS, 6 Hyd RSA/RSR lines	Composites of best products of East African breeding and testing programme (Serere)	ms_3	S_2 testing
Tropical conversion	102 Puerto Rico Popln 41 Puerto Rice Early lines	Heterozygous material from BC_1 or BC_2 of 115 entries from the P R conversion programme crossed to Serere RS population and back-crossed to P R conversion (Serere)	ms_3	S_2 testing
KP1BR	KP1BR	Kansas	a1	S_1 testing
Good grain	Good grain I and II, Red Flinty population	Composites of chosen adapted lines from the World Collection with wide variation in grain size and shape, mostly corneous endosperm (Serere)	ms_3	S_2 testing
West African early	WABC, Bulk Y	W African	ms_7	S_2 testing
Indian diallel	Selections from a diallel of 45 parents	Diallel crosses among World Collection entries tested & selected in India for yield, or pest resistance, or grain quality (India)	ms_3 ms_7 a1	S_2 testing

Table 7 – *continued*

Name of population	Components of population	Source of material —origin	Source of male sterility	Proposed selection method
Indian synthetic	10 elite Indian lines	Rajendranagar lines selected from exotic entries and Indian x exotic crosses (India)	—	S_1 testing for 1 cycle
RS/B	Maintainer RS and PRS	Mixtures of 2/3 RS and 1/3 PRS recombined after 3 generations of mass selection or 1 cycle of S_1 testing	ms_3	S_2 testing
RS/R	Restore RS and PRS populations	Mixture of 2/3 RS and 1/3 PRS recombined after 3 generations of mass selection or 1 cycle of S_1 testing	ms_3	Reciprocal recurrent selection with inbred tester from RS/B

US/R and US/B

A total of just over 2,600 S_1 lines from these populations were yield-tested in kharif 1974 They were grown in the environments we have described earlier, giving the data set out in Table 6 We selected 104 lines from US/R and US/B, which were recombined in rabi 1974 We observed a high degree of heterogeneity with the S_1 lines and we will switch to S_2 testing for the next cycle

Serere Elite

We grew half-sibs from this population in kharif 1974 on both red and black soils We selected visually, sibbed those chosen, and recombined them in rabi 1974

Tropical Conversion

Three sub-populations were used to form this population (1) a group rigorously selected against excessive height in Hyderabad, (2) another grown in Hyderabad with little selection against height, and (3) one selected for earliness in Serere and received in Hyderabad two generations later than the first two Selected lines from all three sources were combined in rabi 1974

KP1BR

This population, based on an antherless gene gave unsatisfactory performance and was discontinued

Good Grain

We are in the process of compounding this population from three sub populations Good Grain 1 and Red Flinty were developed at Serere from an original population of about 80 entries, Good Grain 2 was developed from Good Grain 1 with incorporation of about 120 additional white corneous varieties The populations are not fully random mated yet, and have too large a proportion of tall, photoperiod sensitive types In rabi 1974 we backcrossed the Good Grain population to AICSIP variety 370 — a photoinsensitive, high yielding, short stature entry with good quality grain We are improving the original population by half-sib testing and will use it as a recur

Part of sorghum germplasm, stored in a temporary cool room to maintain viability for 5–7 years. Definitive storage will keep the seeds much longer.

rent parent. At least two backcrosses will be made.

West African Early

Materials from several sources are going into this single population: photoinsensitive selections from the Nigerian WABC and Bulk Y, which are based on the ms_7 gene; several elite lines from Pickett's nursery crossed in during rabi 1974; photoperiod insensitive segregates from crosses with pest-resistant parents. We plan to introduce other segregates from crosses involving Naga White, a variety with early seedling vigor.

Indian Diallel

This population originated from 45 entries of the world collection, chosen for yield, pest resistance or grain quality. F_1 generations of 360 crosses made with ms_3, 309 crosses made with ms_7, and 377 crosses made with antherless were grown in kharif 1974. The first backcrosses were made in rabi 1974 to 640 lines selected from the diallel. The final population will be made from two backcrosses followed by random mating, using material carrying both ms_3 and ms_7 genes (the crosses to antherless will probably be discarded). This population will have a broad cytoplasmic base, since the male sterile sources were used initially as pollinator parents.

RS/B and RS/R

We are seeking to improve these populations by reciprocal recurrent selection, using an inbred tester. Lines withdrawn from RS/B are converted into cytoplasmic sterile A lines, while S_2 testing proceeds simultaneously to improve the RS/B population. These cytoplasmic A lines will be used as testers to improve the RS/R population. The two populations were brought under half-sib testing on red and black soils in kharif 1974.

Indian Synthetic

This new population includes 7 lines from AICSIP, 1 Pioneer hybrid (22E) developed in India, CK 60B, and a selected 2KX line from East Africa. Development plans include Jensen's diallel selective mating system and S_1 testing for one or two cycles.

Other Sites

The ICRISAT breeding responsibilities include development of material that can be used throughout the semi-arid tropics. Thus, we need to know the areas of adaptation of our populations. Lines withdrawn from nine of the composite populations were multiplied in rabi 1974; these seeds went to several sites in the semi-arid tropics for testing in kharif 1975

Pearl Millet Improvement

Our pearl millet improvement program draws on 4,553 lines, varieties and populations assembled at Hyderabad. The largest share of those materials are of Indian origin, with other important collections from East Africa and West Africa, as well as other points in the world. The Indian lines tend to be dwarf and early with thin stems and numerous tillers, small heads that ripen together, with small grains; the plants lack high levels of resistance to downy mildew, ergot or rust.

African lines, especially those from West Africa, tend to be taller and later, with fewer but larger heads with more grain mould resistance and dormancy: The plants have considerable resistance to the major disease threats — downy mildew, smut and rust.

Indian lines tend to be dwarf and early with numerous tillers.

Previous work with the world collection has shown that good combining ability exists between the Indian and African materials. Our observations on crosses in the ICRISAT program confirm this and add that equally good combining ability exists between East and West African sources.

Our breeding program efforts in pearl millet take us along three main lines. We are developing breeding populations (composite) and improving them through methods of recurrent selection to give experimental varieties; inbreds can also be drawn out from the best population progeny; hybrid parents, synthetics, and entries for new populations will be derived from the variety cross program. In our second year, we are still in the early stages though the work moves rapidly, since irrigation permits us to grow three crops each year: the main kharif crop, planted in June and harvested in September and October; the rabi crop, planted in October and harvested in February; the summer crop planted in March and harvested in late May and June.

Population Improvement

Our population breeding program embraces three main sections. We are applying selection pressures to improve the qualities of current populations or advanced composites; we are doing some crossing between populations to introduce improvements; and we are developing source composites which have certain agronomic values.

Advanced Composites

In our first year of work at ICRISAT, we formed four composites from a total of 550 lines. A *dwarf composite* was compounded from all (86 lines) materials shorter than 1.8m; three composites

World Collection accession from Chad

were made based on maturity groups — 194 entries taking less than 45 days to bloom at Hyderabad (in the kharif season) formed the *early composite*, the *medium composite* — 45 to 55 days — included 197 entries, and the *late composite*, more than 55 days, was formed with 46 entries

These composites were grown through three random matings, using a method with alternating rows of weighted bulk and inbred which allows genetic recombination while yet maintaining maternal identity We selected 1,000 half-sibs in each composite In rabi 1974 we selected 545 S_1 plants in the early composite and 519 in the dwarf, with plans for testing the S_2 lines at two or three locations in India where downy mildew, smut or rust are known to occur with high severity Five hundred full sibs each were made in the medium and late composites for tests at three locations in India and one in West Africa

Nigerian Composites

Four Nigerian composites were included in our first year's breeding program In kharif 1975 two replications of each of the four were grown as S_1's, the S_2's were grown and harvested in the following rabi season One composite — Ex Bornu (S) C_1— was not impressive either in yield or in variability, and it was diverted to our source composite program Nigerian Composite 3 was the best performer mean yield of S_2 lines was 2,578 kg/ha, with individual lines varying from 373 to 4,796, genotypic variance for grain yield was 2 19 times larger than error variance, heritability in the broad sense was 68 6 percent The composite is in the mid-late maturity class and it should have good resistance to downy mildew

Two other Nigerian composites are being retained in this phase of our program Here is the summary of testing and selections of the S_2's for three composites:

	S_2 lines tested	Number selected for recombination
Nigerian Composite 3	230	56
N x W Composite 2	231	101
World Composite	205	109

We also selfed within the selected S_2 lines of these three composites and also in two other *Nigerian segregating populations* (Maiwa New Strain and Gero New Strain) and crossed these plants to ms 5071A. The resulting F_1 hybrids were tested in kharif 1974, with 96 hybrids retained for the hybrid program.

Senegal Dwarf Composite

A Senegal dwarf synthetic (M) C_2 originating from CNRA, Bambey, had undergone two cycles of mass selection for downy mildew resistance at Kano, Nigeria, before it reached our program. We produced 270 S_1's for testing in kharif 1975. The population is dwarf, with plant height about 120 cm and head length as much as 60 cm. Our goal is to further improve the population for downy mildew resistance and seed set.

Downy Mildew (Green ear) disease of pearl millet.

Serere Composites

Six Serere composites from Uganda are morphologically similar — tall, early, with good combining ability with Indian and West African lines. We produced about 200 S_1's from each of the six for testing in kharif 1975. We plan to pool the best into one composite.

R and B Composites

R and B composites underwent random mating in rabi 1974. The R bulk includes 171 good restorer entries drawn from a large number of test crosses on $23D_2A$ grown in the preceeding season. The complementary B bulk includes 111 maintainer entries. We hope to develop other R and B composites related to other cytoplasmic male sterile systems. We would improve them through a reciprocal full-sib system.

Maiwa A and B

Maiwa A and B bulks—the result of one backcross of Maiwa by 23B—came to our program from Nigeria. Maiwa is a photosensitive Nigerian land race with particularly good resistance to downy mildew We observed wide variation in height and maturity in these bulks. In rabi 1974 we made plant-to-plant crosses to obtain pure lines. Also we crossed Maiwa B with six other cytoplasmic maintainer lines and to other male sterile lines.

Top cross testing in rabi 1974 was pointed towards determining combining abilities of several populations. The approach involved crossing individual S_2 plants as females from one population and mass pollen from the other. The crosses made are reported in table 8.

Evident variability for head type in a Breeders Composite from Serere, Uganda.

Table 8.		
S_2	Mass pollen	Number of Crosses
World Composite	Cassady dwarf population	48
World Composite	Senegal dwarf synthetic	48
World Composite	Sauna D_2	48
NxW Composite	Cassady dwarf population	38
NxW Composite	Sauna D_2	38

Source Composite Project

Our Source Composite project began in rabi 1974. The project involves 11 populations which, in themselves, lack merit for the recurrent selection program but which contain useful variability. The populations include Cassady's dwarf from U.S.A.; Mokwa-Maiwa, Maiwa; Early dwarf and Ex Bornu (S_1) C_2, from Nigeria; and six populations from Uganda. We hope to form source composites for dwarfness, downy mildew resistance, rust resistance, and drought tolerance in the near future.

Variety Crosses and Synthetics

We are generating new variation by crossing inbreds and varieties that complement each other. Desirable selections from the F_2's and F_3's will be intercrossed. Derived lines will be usable as inbreds, as new hybrid parents, for synthetics, or as entries for composites to be brought under recurrent selection.

In the short summer season 1974, we grew 166 F_1 observation rows. These included Indian elite lines crossed with various Nigerian and Ugandan lines. Performance of the five best variety hybrids is shown in table 9 — best performers were Jamnagar hybrids crossed with materials from Nigeria.

Table 9.	
J 1249 x 700544	6,668 kg/ha
J 934-5 x World Composite	6,294
J 1623 x 700797	5,547
J 1644 x 700594	4,912
J 1798 x Gero New Strain	4,907

In kharif 1974 we grew populations of 750 to 1,000 F_2 plants each of 148 crosses. Ergot and rust infection was heavy, and we selected 565 plants that showed less ergot and rust; downy mildew infection was not intense enough to permit selection for resistance. Plants selected in this group were early maturing, dwarf to semi-dwarf in growth.

The next step with these materials came in rabi 1974 when the 565 F_3 progenies were grown. We made 708 selections from 119 F_3 families, and preliminary test crosses to ms lines were made with 50 of them. We considered 95 progenies as uniform and particularly promising.

A further phase in this project began in the summer 1974 season, with 599 new variety crosses involving a wide range of Indian and exotic materials. We selected 79 phenotypically desirable F_1 hybrids from these crosses. At the same time F_2 seeds were used to develop an intervarietal synthetic (IVS), grown in its first random mating in rabi 1974. We rejected 15 hybrids during this stage for poor performance and harvested 1,000 open pollinated plants from the remainder to produce S_1 lines. There may be the basis for one or several synthetics and, depending upon variability, the whole population may be suitable for a composite to be improved by recurrent selection.

Populations of these same 79 F_2's were grown in rabi 1974. In addition to 349 single plant selections, 25 of the populations were identified for possible use by other breeders in the semi-arid tropics. We harvested open pollinated bulk seed from these 25 populations.

We developed an RF Synthetic with selfed seed of 190 good single cross fertile hybrids grown for first random mating in kharif 1974 and second random mating in the following rabi season. We observed high tillering ability but poor seed set. We will review its future, based on kharif 1975 performance, particularly in relation to ergot infection.

Hybrid Program

Our main goal in the hybrid program is to identify elite combinations which have high yield and tolerance for disease and drought. We are producing new inbred material containing either potential pollen parents or potential seed parents.

From observation plots in summer 1974, we harvested 904 new hybrids, using three ms lines as seed parents. Thirty-eight yielded more than 3,000 kg/ha; the best five ranged from 4,534 to 5,041 kg/ha. Best performance came from hybrids made with $23D_2$ as the seed parent. Of the 38 restorers, 17 were of Indian origin, 3 from the United States, 16 from Nigeria, and 2 from Uganda.

Seed from 1,567 new hybrids was grown in kharif 1974, from which we selected 44 for direct entry into replicated field tests. We made only 123 crosses in the season — rain and humidity make seed production under bags difficult because of rain damage to the bags and covered heads.

To this stage in our program, we had used four ms lines, all in the A_1 system. We brought in additional test lines from the A_2 and A_3 systems, using eight ms lines in the rabi 1974 crossing program. In that program we made about 2,500 crosses, including 133 variety top crosses with Ugandan and Nigerian populations.

In a line x tester study in summer 1974, we compared combining abilities of the three female parents we had been using; the 81 pollinator parents used included 46 Indian, 22 United States, 11 West African, and 2 East African materials. The hybrids did not differ significantly in ear girth, but we could identify some differences in other factors recorded for the 243 crosses. Those factors were plant height, ear length and grain yield. The best combiner among the seed parents was $23D_2A$ — which, however, is susceptible to downy mildew. For that reason we have made crosses with $23D_2B$ to resistant sources. We would like to develop a good D_2 (i.e. dwarf) seed parent to widen the range of possible hybrids; there are many good dwarf pollinators that would be difficult to use commercially since they are shorter statured than the seed parent.

In the test cross program we routinely bag a few heads and inspect for seed set. The purpose is to check for potential seed parents that maintain male sterility. In summer 1974 we found 13 lines that were both agronomically suitable and which maintain male sterility. Eleven have been backcrossed and have gone into testing for disease reaction. Dwarf line J 1352 seems to be the best of the eleven.

Yield Trials

The kharif season, June planting and October harvesting, is the main period for yield tests. Three trials were carried out in kharif 1974. Observations recorded include days to 50 percent bloom, plant height, lodging percentage, head count, ear length, weight and girth, seed size, protein content, and grain yield.

In one trial 23 experimental hybrids were tested. Three yielded notably better than HB 3, a hybrid from the Indian millet program that is widely used as a standard check. The three high-performers yielded, respectively, 24, 26 and 38 per cent over HB 3.

Two ICRISAT bulk composites were grown with leading released hybrids from the Indian program. Their yields — 3,016 kg/ha by the mid-late composite and 2,989 kg/ha for the early composite — were not significantly different than the established Indian hybrids.

We cooperated with the All India Coordinated Millet Improvement Project in conducting five yield trials under different moisture levels at Hyderabad in 1974. The conditions under which the trials were conducted and the top three performers in each are given in table 10.

Three yield trials were conducted in the rabi season of 1974. Six of our experimental hybrids yielded better than the check, HB 3: $23D_2A$ x Ghana; $23D_2A$ x Serere Composite 1 (S) 4; $23D_2A$ x J 128-3; $23D_2A$ x 700250; $23D_2A$ x 700651; and $23D_2A$ x Old Jamnagar. Their superior

Table 10. Summary of performance in All-India Coordinated Millet Improvement Trial. Hyderabad 1974.

Condition	No of entries	Yield of HB 3 kg/ha	Three best hybrids Parentage	yield kg/ha	Mean kg/ha
Arid	20	1,740	23A x J 108	2,453	
			$23D_2A$ x J 41	2,273	1,719
			$23A_2$ x J 87	2,093	
Limited moisture	23	1,853	$126D_2A$ x J 1270	2,040	
			5071A x D 111	1,966	1,521
			HB 3	1,853	
Adequate moisture	21	1,920	$126D_2A$ x J 1270	2,313	
			PHB 12	2,260	1,752
			5071A x D 95	2,026	
Preliminary evaluation I	32	1,288	$126D_2A$ x J 1986	2,044	
			$126D_2A$ x J 1925	2,022	1,468
			$23D_2A$ x D 32	1,844	
Preliminary evaluation II	13	1,206	$126D_2A$ x J 1270	1,646	
			$123D_2A$ x J 1270	1,580	1,104
			$126D_2A$ x J 1399	1,366	

performance ranged from 21 to 64 per cent above HB 3 The ICRISAT dwarf and early composites were grown in a trial with six entries from the India program, no significant differences were found within a performance range of 867 to 1,301 kg/ha

In all these yield trials in kharif 1974, situational factors let us add other observations One fact was a severe attack of ergot, the other was late rains — in September, which resulted in lodging

International Cooperation

One ultimate purpose of ICRISAT is improved on-farm performance of pearl millet throughout the semi-arid tropics The two-way flow of international cooperation helps us work toward that purpose we are gathering breeding material from other sources, and we are furnishing material for performance testing under other conditions Also we furnish seed that other breeders may find useful in their local programs

In this report year 1,646 seed lots went from ICRISAT to 16 other countries New seed lots came to us from Niger, Senegal, the Arids Lands Agricultural Development program in Lebanon, the United States, and India

The international dimension will enlarge in the coming year We have assembled material of three classes for distribution in 1975

1 Sixty experimental hybrids

2 An observation nursery of 13 entries plus a local check variety

3 Breeder's material including intervariety F_1, F_2 and F_3 bulks, some F_4 seed and a group of 25 entries from the working collection

The experimental hybrid trial is scheduled for testing at three sites in India and one in Senegal We have identified 15 other locations for work with the other two sets of materials In addition, we will cooperate on a project in Upper Volta for a planting of a range of breeding material appropriate to West Africa

Cereal Physiology

Systematic investigations of cereals physiology began at ICRISAT with the rabi season 1974-75 Our main early work deals with four attributes related to yield carbohydrate pro duction and distribution, panicle development nutrient uptake and distribution, and response to drought stress We need to assess and un derstand the variability in these attributes as de rived genetically and through the interaction of genetics and environment Our goal of course is to provide information to the breeders that will help them develop populations and varieties with the optimum balance of attributes that in fluence final yield

Sorghum

In the first round of studies, we observed seedling vigor of 27 sorghum genotypes Larger seeds produced vigorous and large seedlings generally but that was not observed in all cases The large, rapid emerging seedlings had a faster uptake of water before germination and a higher efficiency of mobilization of seed reserves Within a given maturity class, the total dry weight of the plant in the 15 to 30-day stage appears to be positively associated with total dry weight at physiological maturity — but not necessarily as sociated with grain yield We observed large variability in the partitioning of seed reserves in to root and shoot and considerable variability in root morphology studied in the seedling stage to panicle initiation

The variety Naga White produces seedlings with early vigor We crossed it with a range of parents, including NP, WABC, and Bulk Y Using Naga White and CSH 1 as checks, we evaluated 66 of the crosses for early seedling vigor Some of the crosses performed better than the checks, showing better efficiency of mobilization of seed reserves and rate of growth in the period sampled, from emergence to 15 days

We began a two-season study of growth and development of a number of hybrids and their parents We are investigating the physiological basis for heterosis in these materials These high yielding hybrids have different pollen and seed parents and they vary in days to maturity The study gathers data on dry matter production and distribution and developmental change in leaf morphology in three growth periods GS1 planting to panicle initiation GS2, panicle initia tion to flowering, and GS3 flowering to physiological maturity In the first season, we ob served considerable variation in lengths of growth stages internode length leaf size and number rate of leaves produced in the first two stages seasonal growth rate rate of grain filling seed size and number Our analyses seek as sociations between these attributes

Our next steps in sorghum physiology will deal with nitrogen and phosphorus uptake and dis tribution and related carbohydrate source sink We will put a range of genotypes under drought

Dr A H Kassam examines ICRISAT germplasm collection for their morpho-physiological attributes stress Our goals include working out a field technique to identify drought-tolerant material and relating characteristics of root systems to response to water and nutrient stress We plan to start studies of the physiological basis of narrow and wide adaptability of plant material, using different testing sites and different environments

Pearl Millet

Physiological investigations with pearl millet followed lines similar to those in sorghum The study of hybrids and their parents includes work with HB 3, HB 4, and HB 5, HB 3 and Mel Zengo are the focus of study of panicle development, 45 genotypes are involved in the study of leaf morphology, growth stages and yield components, and 50 genotypes are included in water stress study

Growth analyses of millets disclosed considerable variation in characteristics length of plumules ranged from 2 6 to 6 cm, length of radicle, 4 4 to 10 cm, number of lateral roots from almost none to 17 per plant, length of the growth stages varied, also, as did the number leaves produced Investigation of seed size and seedling size showed that large seedlings resulted from large seeds only when the efficiency of mobilization of seed reserves was high

Fifty genotypes were subjected to three water regimes in the study of drought tolerance The water treatments included a check, 30 days without water during the GS2 stage — panicle to flowering, and continuous dry from the start of GS2 onward These trials had not been harvested at the end of the report period, but large differences were apparent visually

As we move ahead with physiological study of pearl millet, we will parallel the study of nutrient uptake noted for the sorghums Study of bases of wide and narrow adaptation will also be pursued The anatomical study of panicle development on millet will be expanded into a systematic study of the anatomy of the entire plant

Cereal Pathology

Sorghum

Grain Moulds

A review of the literature revealed that about 20 fungal species are associated with sorghum grain moulds. At ICRISAT in kharif 1974 seven genera of fungi were isolated from mouldy grain, viz., *curvularia* spp., *Fusarium* spp., *Colletotrichum* sp., *Phoma* sp., *Helminthosporium* sp., *Penicillium* sp., and *Olpitrichum* sp. Out of these, *curvularia* and *Fusarium* were most prevalent. Grain affected by *Curvularia* and *Fusarium* failed to germinate almost totally (germination 1 per cent or less), while *Colletotrichum* infection caused a significant reduction (47.25 per cent germination). Species of *Curvularia* and *Fusarium* were parasitic and in inoculations using polythene bags to cover the heads made 4 to 5 days after the initiation of head emergence in case of *Curvularia,* and 3 to 7 days in case of *Fusarium,* seed development was completely prevented

More than 2800 entries of the breeding material were evaluated for their reaction to grain moulds in kharif 1974 when the incidence of grain moulds was high under natural conditions On a 1-5 rating scale 24 entries were given a rating of 1 In rabi 1974-75, about 280 short duration lines were screened artificially with a mixture of *Curvularia* and *Fusarium,* out of which 26 were given rating of 2. Most of these lines are brown seeded types.

Downy Mildew

Downy mildew *(Sclerospora sorghi)* incidence was low in kharif 1975 both in breeding plots and in the plot where oospore inoculum was incorporated to develop a 'sick plot'. A long term pot study on the survival of the oospores of these two downy mildews was initiated, to determine the longevity of oospores in different soils under various crop rotations.

A one-half hectare plot is being developed as 'sick plot' by adding oospore material. By kharif 1976 it should be ready to initiate screening of breeding material for downy mildew resistance.

Observations on other diseases

Low incidence of sugary disease *(Sphacelia sorghi)*, leaf spots (species of *Colletotrichum, Gloeocercospora*, and a few yet to be identified), grain and head smuts was observed in kharif 1974. In the rabi 1974-75, leaf blight *(Helminthosporium turcicum)* was observed in severe form, whereas a little incidence of rust *(Puccinia purpurea)* was noticed. Since the natural incidence of *Helminthosporium* was high, about 11,000 germplasm lines were evaluated for resistance. Twenty five lines were found free. Charcoal rot *(Macrophomina phaseoli)* was observed in February-March 1974 in small patches in the breeding block.

Pearl Millet

Pearl millet is subject to several serious diseases. In the first phase of the research program, detailed investigations were initiated on downy mildew, ergot and rust.

Downy Mildew

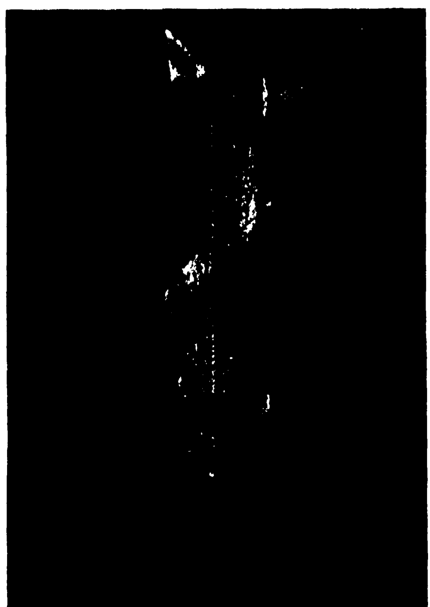
A long term study was initiated on the survival of oospores.

In order to screen the germplasm and breeding material for resistance to downy mildew *(Sclerospora graminicola)*, a 1.5 ha. 'sick plot' is being developed through frequent incorporation of diseased plant debris (containing oospores) and the growing of highly susceptible varieties. It is expected that from 1976 kharif, it should be possible to initiate screening for resistance.

The key to oospores germination is still a mystery. Many treatments were tried for inducing germination without success. Work has been initiated on techniques utilizing sporangial inoculum for infection. Since oospores present in soil and on seed are thought to be the primary and major source of infection under field conditions, seed treatment experiments with newer fungicides, known to be effective against pythiaceous fungi, are being carried out to explore the possibility of reducing initial infection.

Ergot

As yet no reliable source of resistance to ergot *(Claviceps microcephala)* is known.



Downy mildew on a leaf.

The 'green ear' stage of downy mildew.

Pearl millet ear with ergot sclerotia.

Major emphasis is being given to establish techniques for resistance screening. It is possible to grow the inoculum on Kirchoff's medium and to produce infection by spraying a conidial suspension from artificial culture. The best time to inoculate heads appears to be 3 to 7 days after the initiation of head emergence. An experiment on the survival of the sclerotia and conidia has been initiated to assess the role of each of these in the epidemiology of the disease. Since no experimental evidence could be found in the literature on the separation of pearl millet ergot sclerotia from normal seed, a series of experiments using various salt concentrations were conducted. Good separation of seed and sclerotia was obtained by dipping the infected seed in 10 per cent salt solution when all sclerotia and sclerotial pieces floated.

Pearl millet heads inoculated with honeydew conidia from an *Andropogon* sp. developed few long greyish sclerotia which differed in appearance from the normal pearl millet ergot.

Rust

The natural rust *(Puccinia penniseti)* incidence was severe in September 1974, and the reaction of the breeding material to this disease was assessed. In all 5570 entries and 2150 S_1 lines were compared and rated. Up to 60 per cent rust severity (Modified Cobb's scale) was observed on susceptible lines. About 450 entries had less than 10 per cent severity, but none was completely free.

Observations on other diseases

Low incidence of leaf blast *(Pyricularia setariae)* and smut *(Tolyposporium penicilliariae)* was observed in breeding plots.

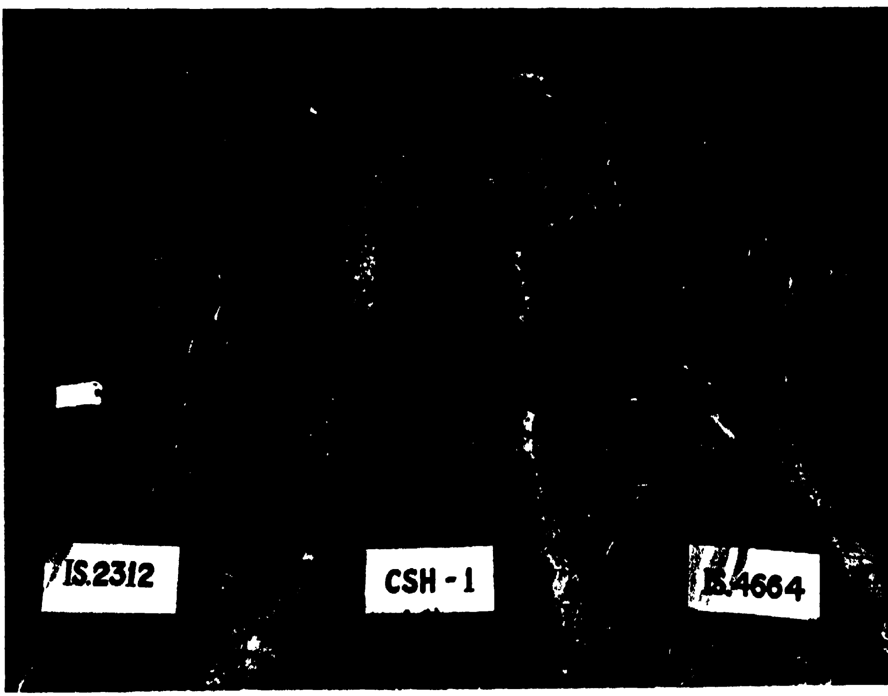
Cereal Entomology

In its first full year of research activity, the Entomology Section concentrated on three main targets

- To assess the pest environment for each of the principal crops in the ICRISAT improvement program — identifying the various insects and looking into the biology of major pests under the conditions at the research site,
- To work closely with plant breeders in the search for cultivars with resistance and tolerance to important pests,
- To assess pest problems, and relevant control measures, for other important crops grown in the Farming Systems research

Pests of Sorghum

At Hyderabad, three pests of sorghum predominate the sorghum shoot fly, *Atherigona soccata* Rond., stem borer, *Chilo partellus* Zell., and sorghum midge, *Contarinia sorghicola* Coq We also found an earhead bug common in the late season, *Calocoris angustatus* Leth., which



Screening of sorghum cultivars for resistance to shootfly, Atherigona soccata *(susceptible check in center)* is a significant pest in parts of India Four species of the shoot-fly were bred and identified from sorghum *A soccata* (the most prevalent, up to 98 percent), *A orientalis* Schn , *A reversura* Vill and *A reversura* ssp nov

As part of a wider taxonomic study of the species of *Heliothis*, it was confirmed that the species attacking sorghum heads, was *Helicoverpa armigera* Hub This insect was more common on compact heads, up to 12 per head being recorded from bagged heads We also found a semilooper, *Hiccoda nigripalpis* Walk We found two undescribed species of pests on sorghum one a *Pyrgomorpha* attacking seedlings, and the other a mite attacking young sorghum plants in the summer season Both are under further study by taxonomists

Shoot-fly Biology

Under the conditions of the ICRISAT research farm, the shoot-fly began laying eggs on sorghum within six days of emergence of the seedlings Oviposition continued for nine weeks from emergence on cultivar CSH 1, with up to 12 eggs laid per plant — about one-fifth of the seedlings had only one egg, numbers above 6 were rare

The peak in egg-laying coincided with the time of maximum dead heart attack at six weeks, at that time 54 percent of the plants showed dead hearts We were surprised to find that 10 per cent of the plants in cultivar CSH 1 contained live *A soccata* larvae nine weeks after emergence

The development period of the fly was within the recorded range of 17 to 23 days during the kharif season The cycle lengthened considerably in the rabi months of January and February, when the final-stage larvae often lodged in the base of the plant These larvae did not pupate readily in the field, but nearly half of the 168 larvae removed from sorghum stems in this stage and placed on soil, in tubes, pupated successfully and produced adults.

Stem Borer

The stem borer, *Chilo partellus*, entered the sorghum crop later than the shoot-fly We found larvae in stem samplings from six weeks after emergence, and a fourth of the sampled plants showed damage from nine weeks on More than a sixth of the stalks contained larvae 17 weeks after emergence

At 15 weeks after emergence on sorghum, we found the first pupae During that same week we observed a secondary peak in oviposition, but the females were probably from an outside source As the sorghum crop matured, most of these larvae did not pupate but went into a torpid stage

In order to get data on carryover of larvae in harvested stalks of three types of material, CSH 1, 302 and diallel material, we built stocks in the field We sampled 200 stalks monthly and found these percentages of stalks infested at the start of the experiment CSH 1, 20 percent, 302, 21 percent, and diallel material, 31 percent By March the percentage of live larvae in the stalks sampled had dropped to 12 percent in CSH 1 and about 6 percent in the other material A high proportion of recovered larvae were parasitized, particularly by Diptera, including three confirmed by The Commonwealth Institute of Biological Control at Bangalore *Sturmiopsis inferens* Tns, *Halidaya luteicornis* Walk and *Carcelia sp* Another common parasite was the hymenopterous *Apanteles flavipes* Cam

Midge

We confirmed *Contarinia sorghicola* as present at the site, but only 13 percent of the plants were infested 13 weeks after germination Attack was first noted at 12 weeks

Resistance Studies

To assure high populations for screenings of resistance, we planted susceptible cultivars three weeks ahead of planting of the test materials, then these plantings were dressed with fish meal to encourage fly activity The result was high shoot-fly attack during studies in both the kharif and rabi seasons

Using the technique, nearly 2,000 lines suspected of having some useful pest resistant attributes from East and West Africa and India were screened Sorghum lines produced by the breeders were also rated for damage Lines confirmed as having high tolerance were IS 1082, 3962, 5383, 5604 In these lines the mechanism of resistance was clearly related to non-preference for oviposition Some lines in these tests, particularly IS 5604 x 23/2 (a West African selection) and IS 3962 x WABC 1023 and IS 2123 x WABC 3121 showed some antibiosis

A screening of material from Coimbatore showed many with marked oviposition non preference features, including IS 4664, IS 1004, IS 2122, IS 2269, IS 2312, IS 4506, IS 4553, IS 4663 and IS 5656 Some lines, notably IS 2129 and IS 4518, had fewer dead hearts than expected from egg numbers laid on them, possibly indicating some antibiosis

Pests of Pearl Millet

No insect reached major pest status on pearl millet during this report period — either on the breeding plots or on the general farm crop Several grasshoppers — including the new *Pyrgomorpha sp* — were observed in light attack, and some *Atherigona approximata* Mall was found This insect is believed to be of increasing importance on pearl millet in some areas of India We also found *Helicoverpa armigera* and several hemipterous species, including *Calocoris angustatus*, but none occurred in threatening numbers The unidentified mite mentioned previously was found on volunteer sorghum in a field sowed to pearl millet, but it showed no partiality to the crop

Looking ahead in Cereal Entomology

On sorghum and millet, monitoring of the pest species and attempts to correlate pest numbers with yield in standard and tolerant cultivars will continue Screening for selection of tolerant cultivars and lines of sorghum under natural and artificially high populations of the major pests will be intensified A start will be made on the determination of physical leaf characteristics important in oviposition in conjunction with ICRISAT physiologists and the Centre for Overseas Pest Research, London

Studies on viruses of potential for control of lepidoptera will be initiated in collaboration with the Boyce Thompson Institute Work on the possibilities of biological control of sorghum will intensify

Work on attractant and pheremone trapping for shoot-fly and stem borer will start Supplies of pheremone will be sent from Dr Nesbitt of the Tropical Products Institute, London

THE PULSES

Pigeonpea Improvement

Experience of the first year of the breeding program, hosting and participating in an international symposium on the improvement of grain legumes, and helpful suggestions from colleagues and breeders in national programs all contributed to giving direction and structure to the breeding program. Exploiting the germplasm sources in a substantial number of crosses of purposefully selected parent lines, emphasizing yield and yield reducers (diseases and insects), and providing breeding material in various stages of advancement to local breeding programs are the basic elements of the program.

Special problems in breeding pigeonpeas are the long duration of the majority of the types, partial outcrossing of an apparent self-pollinator, and the multiplicity of systems in which the crop is grown.

ICRISAT pigeonpea breeder Dr. J. M. Green examines a dwarf type with large seeds developed by West Indian plant breeders.

Photosensitivity

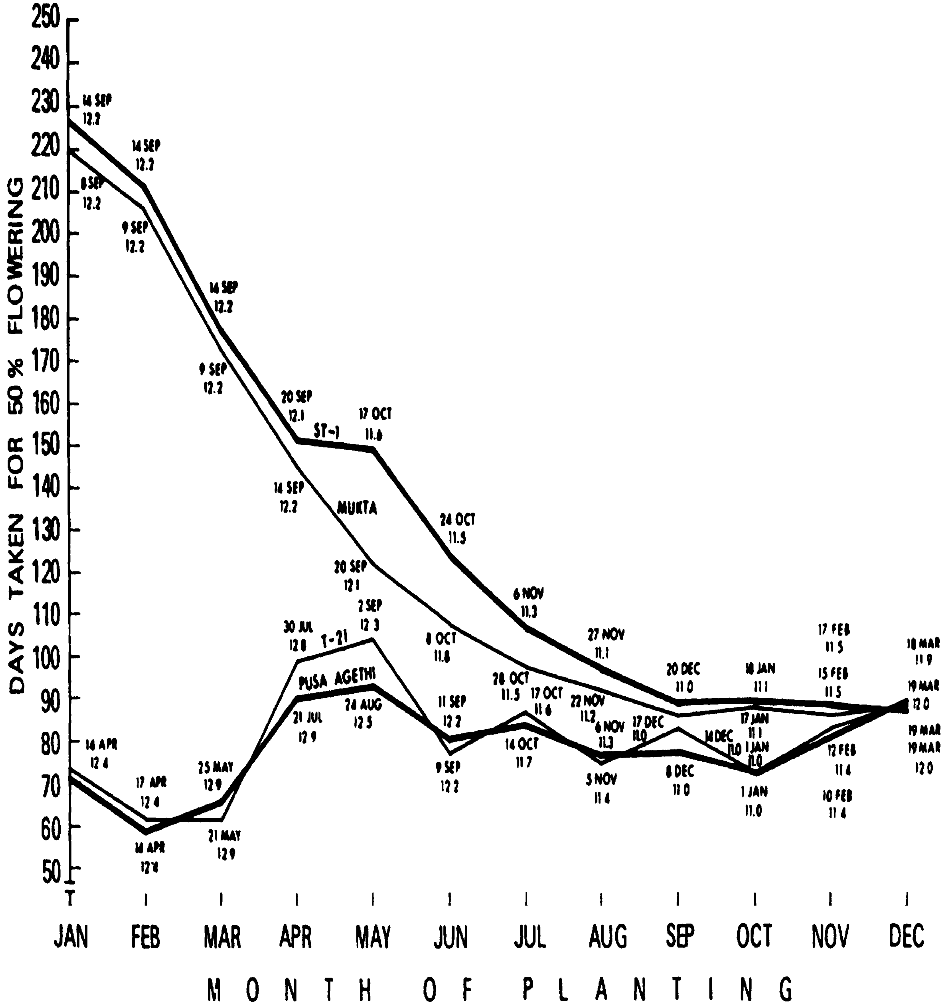
To investigate the possibility of speeding generations in an off-season nursery, we initiated monthly plantings of several cultivars of different maturity in January 1974. (First planting was January 30; subsequent monthly plantings were on or near each twenty-second day.) Figure P-1 illustrates the reaction of two early and two medium maturity types. The early types varied in days to 50% flowering, but they did not show a typical short-day reaction as did the later types. However, it was apparent that both types could be planted in November or December and could be harvested in time for a June planting. On this basis we are using off-season planting to gain a generation per year in the program. To gain further information on day length and temperature reaction, a standard set of cultivars is being planted monthly at four latitudes; 11, 17, 23, and 29 degrees north, with two elevations at each latitude.

Selfing Techniques

Studies on selfing and crossing techniques were conducted. Fine mesh nylon bags are used for selfing in some areas, but the cost of this material is prohibitive in India. We compared

Figure P-1. Flowering response of pigeonpea varieties to different planting dates.

The figures refer to date of flowering and hours from sunrise to sunset



glassine bags and muslin cloth bags to cover one branch and to cover the entire plant All were successful, the muslin bags over the entire plant gave the lowest cost per selfed seed However, in order to select among selfed plants, it appeared best to use the cloth bags to cover one or two branches per plant, permitting the balance of the plant to develop under normal environmental conditions

Hand Crossing

Crossing has been found to be feasible throughout the day, and we emasculate and pollinate a plant on the same day Flower drop, a natural phenomenon in pigeonpea, contributes to the low success percentage in making crosses Average pod set was 19 74% in 447 000 hand pollinations made during the year When early parents were ratooned to delay flowering, a higher success percentage was observed when flowers on the ratton were pollinated The effect of ratooning was greater in early than in medium types, as illustrated in the following comparison

Cross	Percentage pod setting	
	Non ratooned	Ratooned
Early x early	14 39	35 50
Early x medium	9 63	20 08
Early parents	8 26	29 02
Medium parents	11 00	11 13

Genotype Stabilization

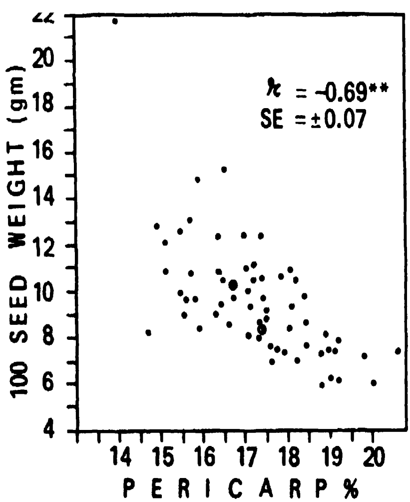
Observation of parent lines indicated all were non-unniform to varying degrees, and variability in F_1 hybrids reflected and emphasized the extent of variation in the parents To have stable reference genotypes, we initiated purification of the parent cultivars by selfing selected progeny rows from 7 early and 21 medium maturity types When we achieve stability, mass selfing and/or increasing seed in isolated plots will be done

The importance of plant characters in different production systems is under investigation by both agronomists and plant physiologists Little hard data is available to guide breeders in establishing specific selection criteria at this point, until good indications are available, we will select for yield, ignoring plant type

Yield Components

Breeding goals include development of high yielding genotypes of early, medium, and late maturing types Selection for pod number per plant, seed per pod, and seed size (components of yield) is common to all types While we observe compensatory effects — large-seeded types, for example, generally set fewer pods — experience with other species would indicate the yields can be increased without fixing extremes of seed per pod or seed size Any incremental increase in seed size would tend to increase the value of the cultivar to the processor also, as indicated in fig P-2, which shows reduced pericarp percentage associated with increased size

Figure P-2. Relationship between 100 seed weight and pericarp percentage.



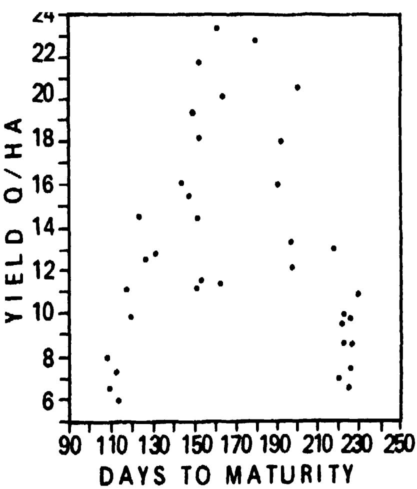
Local Adaptation

Selection for superior genotypes in the three maturity groups apparently cannot be equally effective at one location A total of 47 cultivars were tested, with a maturity range of 92 to 229 days, and highest yields were obtained with 160 to 170 days to maturity Figure P 3 illustrates the severe depression of yields in the extremes of early and late types These same late cultivars, grown in North India, produce excellent yields, as do the early types grown in North India also This information has led to the advancing of bulk hybrid populations without selection for later selection in other areas, and to seeking cooperation in such locations

Segregating Populations

The first F_2 populations were grown in the off season nursery, and included 13 early x early, 23 early by medium, and 12 early by large seeded crosses These 48 crosses were selected from 107 F_1 hybrids grown during the kharif season

Figure P-3. Yield versus days to maturity in 39 cultivars tested on black soil at ICRISAT in kharif 1974.



Crossing Program

Crosses made included a 28 parent diallel a diallel of 10 germplasm groups intra group crosses in 9 of these groups 34 miscellaneous crosses 37 triple and one double cross In all cases the purpose is to bring together diverse germplasm and to combine traits of the different maturity groups Parents used in crosses to date total 67 in addition to variations in plant size shape and structure variability in some other characters is indicated below

Days to 50% flower	79	171
Days to maturity	114	234
Seed per pod	3 0	5 4
Grams per 100 seed	6 1	22 2
Percentage protein (in dhal)	19 14	28 00

Germplasm Groups

The germplasm groups were assembled from 3 480 germplasm collections grown in 1973 74 The purpose was to test the concept of reducing numbers in germplasm banks and using the composites of similar types as source material Information on some characteristics of the groups is given in Table 11 The groups will be grown each year under isolation with comparison of the inter and intra group crosses

Selection in Germplasm

With slightly over 4 000 germplasm collections being grown, selection of high yielding individual plants seemed worthwhile Since there was a possibility of isolating types that might be directly usable as cultivars we emphasized the maturity group best adapted to the Hyderabad location Using visual criteria we selected 1,550 plants in the field final selection was based on individual plant yield Table 12 displays means for the selections and the original population of 1,550 plants

These plants will be evaluated as progeny rows, and those selected will be evaluated in

Table 11. Number, source, and some characteristics of germplasm collections placed in 10 broad groups.

Group	No of cultures	Source	Plant type	Height	Grams per 100 seed	Days to 50% flowering
1	1	India	Compact	Short	7 90	80 3
2	24	India	Spreading + semi-spreading	Medium	7 76	85 9
3	14	India	Compact	Tall + medium	7 20	118 4
4	1594	India	Semi spreading	Tall + medium	7 23	111 1
5	1253	India	Spreading	Tall + medium	7 38	103 2
6	11 25	India Puerto Rico	Spreading + semi spreading	—	14 35	131 6
7	46	India	Spreading + semi spreading	Short	8 08	97 2
8	68	India	Compact	Tall + medium	8 44	150 8
9	9	India	Spreading + semi spreading	Short	7 84	143 7
10	435	India	Spreading + semi spreading	Tall	7 71	144 0

Table 12. Means for selected sample and population and selection differentials for the various traits.

Material	Days to 50% flowering	100-seed wt in g	Individual plant yield in g
Selections	135 26	8 55	236 93
Population	133 18	9 24	106 63
Sel differential	2 08	−0 69	130 30

preliminary yield trials We hope they are sufficiently homozygous for the rigorous selection for individual plant yield to be meaningful

Male Sterility

Male sterility has been reported in pigeonpea in early genetic studies Since the character is potentially useful in the breeding program, and earlier sources were not available, a search was made in the germplasm Detection turned out to be easy, for the reduced seed set resulted in delayed maturity A total of 76 plants in 24 different sources were found six had translucent anthers, 37 normal-appearing anthers in normal flowers, 20 were long-styled heterostyles, 9 were short-styled heterostyles, 4 partial heterostyles (varying levels), and 1 had grossly modified corolla structure Percentage of viable pollen varied in the abnormal types, and it is possible self incompatability could account for the reduced pod set in some cases The empty-anthered, normal flower structure types will be studied and transferred to lines in the breeding program The feasibility of producing F_1 hybrid seed will then be investigated The sterility will also be used in breeding methodology studies

Protein Screening

Screening germplasm lines for total protein has been the major effort so far We have found a range of 13 1 to 25 1 percent in 2,286 samples tested as whole grain Following a determination at that point that there was a weak correlation (r= 0 33) between whole seed and dhal protein percentage, later samples were tested as dhal (with pericarp removed) and the range in 2,172 samples was 13 5 to 27 6 percent

Since pigeonpea is deficient in the sulfur amino acids, methionine was measured in a few samples with a range in protein percentage Results were as given in table 13

From this limited sample it would appear that little variation in methionine exists, and that breeding for higher protein would provide more methionine to consumers of higher protein pigeonpeas However, much more exploratory work will be done before objectives for quality improvement are established Bioassay for methionine and cystine and tests for total sulfur on a large number of samples are being made at outside laboratories, and studies of environmental and genetic effects on protein are in progress

Table 13. Protein and methionine in selected cultivars.

ICRISAT number	% protein in dhal	Methionine	
		g 100+g protein	g 100+g sample
1180	27 12	1 12	0 304
3868	27 89	1 09	0 304
3816	28 00	1 08	0 302
7065	25 16	1 09	0 274
10	22 24	1 11	0 247
3783	19 14	1 10	0 211

International Cooperation

An adaptation trial consisting of 45 cultivars selected to represent a wide range of maturity and plant characters was furnished to 12 locations in 10 countries The objective is to identify the most promising types for each location

Working relationships with Indian institutions were strengthened by (1) inviting pulse breeders to ICRISAT to select material for their programs, (2) making personal visits to nine important pigeonpea research centers, and (3) providing 46 F_2's, 238 F_1's and 375 F_3 lines to 18 breeders Outside India, seven countries were visited, and 8 F_2's and 1 F_1 were furnished to four breeders

A grain legumes workshop with special emphasis on chickenpeas and pigeonpeas was held in January, 1975 The group developed some recommendations for the ICRISAT program, which are reported in the workshop proceedings

Chickpea Improvement

More than 10 million hectares are planted to chickpeas each year worldwide Average yield is little more than 700 kg/ha Those two statistics underscore the importance of the chickpea improvement mission of ICRISAT

Breeding Program

The first chickpea breeding work began in the rabi season 1973-74 when 423 crosses were made among fewer than 100 parent cultivars

Dr A K Auckland, plant breeder and Dr K B Singh, associate plant breeder examining individual chickpea plants within a segregating population

The F_1 progenies of those crosses were grown at two off-season locations — Lahaul Valley in north India and Lebanon — in the first half of 1974

A total of 324 F_2 lines were brought back to Hyderabad for the 1975 growing season there Among that group were 252 based on "desi" by "desi" crosses and 72 were "desi" by "kabuli" ("Desi" refers to the small-seeded, many colored lines common to East Asia, where about three-fourths of the world's chickpeas are grown, the "kabuli" is a larger-seeded, white grain type common in West Asia)

In the 1974-75 season at Hyderabad, breeders selected 3,817 individual plants from the 324 F_2 populations The populations were divided into four classes, from "very promising" to "poor " Individual plants were chosen from each class in the numbers reported in Table 14

More crosses, this time involving 294 cultivars, were made for the 1974-75 season at Hyderabad 1 056 single crosses and 613 multiple crosses The success ratio of the crosses was 24 percent, compared to 13 percent in our first season In these crosses we emphasized the "desi" by "kabuli" lines, seeking to introduce the genetic diversity needed if we are to achieve large yield increases About one-third of the parents in these crosses came from outside India (table 14)

Cultivar Adaptation

Performance tests were conducted with 126 chickpea cultivars in the 1974-75 season Table 15 presents data from the five best lines in each of the yield trials. At the low end of yield was 702 kg/ha in the 100-cultivar test group and 1,395 kg/ha for the 26-cultivar group

The entry called "Bengal Gram," which was the highest yielding cultivar over all trials, was a mixed market sample from West Bengal, in India. This performance may indicate the importance of a population buffering as a factor for stability of yield

Response to Fertilizer

There is a widespread view that chickpeas respond little to fertilizer We tested this proposi-

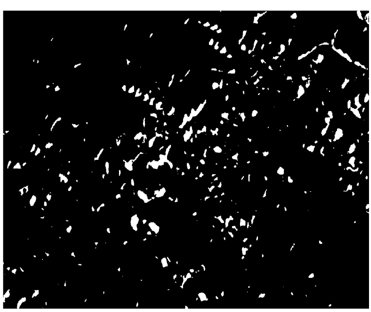
Table 14. Classification of F_2 populations and plant selections at Hyderabad, 1974-75.

Class	F_2 populations		Number of plants selected		
	Number	Percent	'Desi'	'Kabuli'	Total
Very promising	31	9 6	827	57	884
Promising	70	21 6	1 245	129	1 374
Difficult to ascertain	108	33.3	1 037	148	1 185
Poor	115	35 5	349	25	374
Total	324	100 0	3 458	359	3 817

Table 15. Yields of five cultivars performing best at three locations with two test groups. 1974-75.

Cultivar	Origin	Yields in kg/ha for locations			Mean
		Lebanon	Lahaul	Hyderabad	
100-cultivar Trial					
Bengal Gram	India	1 889	2 824	2 245	2 319
K 4		1 472	2 222	2 350	2 015
P 2974	Iran	1 736	2 546	1 701	1 994
P 3284	Iran	2 472	1 896	1 481	1 950
V 4	Mexico	2 360	1 896	1 280	1 845
*Lowest mean yield of 100 cultivars, 702 kg/ha					
26-cultivar Trial**					
T 3	India	2 233	2 592	2 077	2 300
B 110	India	1 455	3 038	1 524	2 005
C 214	India	1 544	2 569	1 899	2 004
Annegiri	India	1 445	2 621	1 921	1 996
Pant 102	India	2 066	2 175	1 748	1 996
**Lowest mean yield of 26 cultivars, 1 395 kg/ha					

Chickpea has a small flower and emasculation is tedious. We employ 50 people each season for crossing and can therefore make thousands of crosses.



One of our high yielding F_2 segregants. Seed from this will be grown next year as progeny rows in different environments and under conditions of high and low fertility.

Table 16. Cultivars giving largest positive and negative response to two rates of fertilizers. Hyderabad 1974-75.

Cultivar	Origin*	Yield in kg/ha		Difference
		Low Fertilizer	High Fertilizer	
P 36	Uttar Pradesh	1 561	2 597	+ 1 036
P 1363 1	Uttar Pradesh	1 381	2 084	+ 703
Radhey	Uttar Pradesh	1 292	2 022	+ 731
P 1236	Uttar Pradesh	1 420	2 117	+ 697
NP 34	Maharashtra	1 536	2 203	+ 667
(740x940) 5 7	Maharashtra	2 042	1 333	− 708
T 18	Maharashtra	2 231	1 625	− 608
P 234	Uttar Pradesh	2 022	1 420	− 603
B 110	West Bengal	2 236	1 642	− 595
P 3951	Iran	1 970	1 445	− 525
LSD (5%)				± 487

*All origins in India except P 3951, from Iran

Two replications each at the two fertilizer rates in kg ha Low 14 N 35 P_2O_5 14 K_2O $ZnSO_4$
high 28 N, 70 P_2O_5, 28 K_2O, 25 $ZnSO_4$

tion by screening 498 cultivars for response to added nitrogen, phosphorus, potassium and zinc Overall the mean yield for the higher fertilizer rates, 1,820 kg ha, was significantly greater than for the lower rates, 1,562 kg ha On an individual basis, 24 cultivars showed significant yield response to higher fertilizer, nine cultivars showed negative response to higher rates, which was statistically significant

We do not have a proven explanation for the negative response It may result from early vegetative growth stimulated by the higher fertilizer additions, which may be a detriment when soil moisture becomes limiting later in the growing season

Table 16 sets out yield responses for the five cultivars that gave the highest increase and the five that gave the largest decrease

Heritability of Seed Size

Seed size is an important factor in consumer choice of grain legumes Large seeds are more desired We carried out one experiment to estimate the heritability of seed size, involving three crosses large by large small by small and large by small Data from three replications at Hyderabad provided the following narrow sense estimates large by large 50 percent, small by small 30 percent, large by small 85 percent

Table 17. Characteristics of parents in chickpea crossing program, with country of origin.

Characteristic	Number of entries	Origin
High yield	147	Afghanistan, Algeria, Cyprus, Egypt, Ethiopia, Greece, India, Iran, Iraq, Israel, Jordan, Mexico, Morocco, The Netherlands, Nigeria, Pakistan, Spain, Sudan, Tunisia, Turkey, U S A
High yield and attractive plant type	5	India, Iran
High harvest index	5	India, Iran, U S S R
Vigorous	7	Afghanistan, India, Iran
Upright habit	9	India, Iran
Tall, erect	16	Egypt, Greece India, Iran, Morocco, Pakistan, Peru, U S A , U S S R
Dwarf	7	India, Iran
Prostrate	1	India
Light penetration	3	India
Good performance under poor conditions	4	India, Turkey
Wilt resistant	2	India
Susceptible to wilt	1	Iran
Blight resistant	18	Bulgaria, Israel, Iran
Drought resistant	1	India
Very early	5	Ethiopia India, Iran
Large number of primary branches	5	India, Iran, Morocco
Large number of secondary branches	6	India, Iran
Large number of pods	24	India, Iran
Two pods per peduncle	25	India, Iran, Pakistan, Turkey, Yozgat
Close podding	1	India
Large pods with small seeds	6	India, Spain
Large number of seeds	20	India, Iran, Pakistan
Large seed size	16	India, Iran, Mexico, Morocco, U S A
Round seed	2	India
High protein content	1	India
High anthocyanin content	1	India
High chlorophyll content	3	India, Pakistan
Red color of leaves	1	India

Pulse Physiology

Intensive efforts to improve pigeonpea and chickpea performance in the semi arid tropics require better understanding of their physiology than is presently available Thus we have begun basic study of the physiology of both crops Our investigations in 1974 75 dealt with growth and yield, root development nodulation and pod development in the two crops

Pigeonpea

For physiological analyses, we grew five cultivars on both the red and black soils They embraced a range of maturities, including two early lines — Pusa Ageti and T 21 two medium — ICRISAT 1 and ST 1, and one late medium — Hy 3C

Growth Analysis

Figure 1 presents growth curves of the two early cultivars grown on black soils in the kharif of 1974 Data were gathered in weekly analyses carried on from germination through maturity

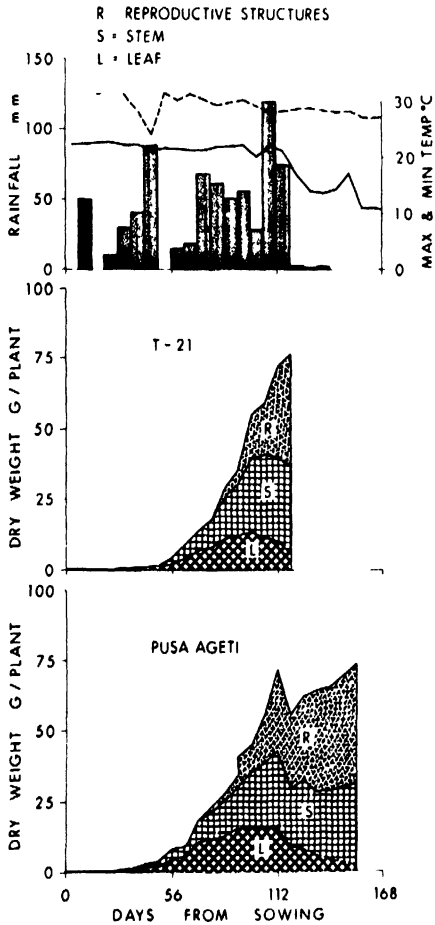
Yield Analysis

Fifty plants of each of the five cultivars were harvested for analysis of yield Table 18 and 19 report grain yield and yield of other above ground plant parts

Seed Size and Seedling Growth

With five cultivars studied, we observed a close relationship between seed size and the seedlings grown from them The 100-seed weights ranged from 19 gm (Hy 3C) and 6 5 gm (T 21) Dry weights of seedlings grown from the seeds lay in the same rank as the seed weights for at least the first six weeks of growth in the field Detailed comparisons were carried out in pots When large and small seeds of the same cultivar were compared, similar results were obtained Moreover, when half the cotyledons were removed from seeds the resulting seedlings grew at about half the rate of the plants from the control seeds These observations suggest that the amount of stored reserves available to the seed has a large effect on the rate of seedling development

Figure 1. Dry matter distribution.



Root Development

We followed root development of Pusa Ageti and ST 1 in black soil through analysis of core samples taken weekly from the field Within 60 days roots had reached a depth of 120 cm under both cultivars Later samples disclosed roots as deep as 150 cm, but more than half the root system was found in the top 30 cm of soil Root development continued after plants began to flower, where flowers were removed to prevent pod development, greater root development continued especially in deeper regions

Nodules

Within 10 days of germination, we found nodulation on all five cultivars in the field Development was strikingly different in the red soils and the black soils most nodules in black soil were small and spherical, in red soils the nodules were larger and branched dichotymously Nodulation was recorded weekly, along with root development data We found nodules throughout entire root systems, even below 150 cm, the majority — ranging from 65 to 95 percent — were present in the top 30 cm The largest

Table 18. Grain yield from five pigeonpea cultivars on red and black soils, Hyderabad 1974-75.

Cultivar	Black Soil					Red Soil				
	Number per plant		Seeds per plant	100-seed weight g	Seed yield per plant g	Number per plant		Seeds per plant	100-seed weight g	Seed yield per plant g
	Pods	Seeds				Pods	Seeds			
Pusa Ageti	95	191	2 01	7 80	14 9	120	235	1 96	8 51	20 0
T 21	112	325	2 90	5 69	18 5	136	408	3 00	6 08	24 8
ICRISAT 1	119	438	3 68	8 77	38 4	171	475	2 78	9 60	45 6
ST 1	153	423	3 76	7 78	32 9	174	550	3 16	7 84	43 1
HY 3C	—	—	—	—	—	78	310	3 97	15 55	48 2

Table 19. Selected plant characteristics measured on five cultivars on red and black soils, Hyderabad 1974-75.

Variety	Black Soil				Red Soil			
	Stem	Pod Wall	Ratio Grain to Pod Wall	Harvest Index	Stem	Pod Wall	Ratio Grain to Pod Wall	Harvest Index
	(grams)				(grams)			
Pusa Ageti	21 9	8 5	1 75	33%	31 0	11 2	1 79	32%
T 21	23 5	11 6	1 56	34%	29 7	13 8	1 80	36%
ICRISAT 1	108 5	23 2	1 65	23%	232 3	20 1	2 26	15%
ST 1	118 0	16 7	1 97	20%	168 3	16 3	2 64	19%
HY 3C	—	—	—	—	113 2	21 5	2 24	26%

number of nodules was recorded at flowering and numbers declined during the reproductive phase

Flower Drop and Pod Development

Eighty to 90 percent of flowers dropped without setting pods That was true for all five cultivars studied The characteristic pattern includes these features on a given branch the lower inflorescences flowered earlier and set more pods on a given inflorescence lower nodes flowered first and set more pods Figure 2 gives the data for ICRISAT 1

When we prevented pod set on lower nodes of inflorescences by removing flowers at those nodes, pods developed from flowers at the higher nodes This suggests that under normal conditions later flowers may tend to abscind because of competition for assimilates for the already developing pods

Detailed studies on all cultivars provided data on pod and seed development We found similar patterns in all cultivars relative to fresh and dry weights of seeds and pod walls Figure 3, using data on ICRISAT 1 illustrates the patterns

Other studies included an anatomical investigation of pedicel pod wall and seed development

Plant Morphology and Intercropping

Pigeonpea is grown as an intercrop in one phase of experiments in the Farming Systems program We sampled pigeonpea plants at maturity in one of these experiments and recorded dry weight and yield of branches borne on 12-node segments of the main stem of each plant We observed that a crop such as setaria which shaded the pigeonpeas seemed to suppress branching at the lower nodes Figure 4 gives data for the cultivar ICRISAT 1 intercropped with setaria and with soybeans

Wind Effects

Strong westerly winds are frequent at the Patancheru site during the June-September monsoon season The winds affect the morphology of the pigeonpeas most of the branches develop on the windward side and hence even after the monsoon is over, a majority of the larger earlier formed branches are found on the westerly side The winds affect plant anatomy too more wood develops on the windward side of the main stem, thickened fibers are found there which show characteristics of tension wood"

Chickpea

Our preliminary studies on physiology of chickpeas began in the rabi season 1974 75 with analysis of growth development and yield on black soils

Growth Analysis

We grew five cultivars that differed in such characteristics as duration growth habit and seed size Data on two cultivars are presented in Figure 5 The shorter duration cultivar — JG 62 — began flowering 49 days after planting, when dry matter accumulation was 1 11 g per plant, the mid late variety — G 130 — had accumulated 3 5 g of dry matter when flowering began 70 days after planting Leaves and stems continued to grow after flowering for 15 days in the shorter duration JG 62 and 23 days for G 130 Little net change in stem weight occurred in either cultivar after those periods There was however a net loss in leaf weight owing mainly to fall of the pinnae most leaf raches remained attached to the plant Active leaf area paralleled changes in leaf weight Cultivars differed strikingly in the extent of the decline in leaf area by the time maximum numbers of pods had been reached The decline in leaf area was 66 percent in G 130 and 33 percent in JG 62 Primary and secondary branches contribute most to yield — 80 percent

Root Development

We took core soil samples weekly to follow the root development of the cultivars JG 62 and T 3 growing on black soils We also took soil moisture measurements As soil moisture declined in the surface layer, root development went into the deeper layers, ultimately less than 10 percent of the roots were found in the surface

Figure 2. Pattern of pod development on racemes of variety ICRISAT - 1.

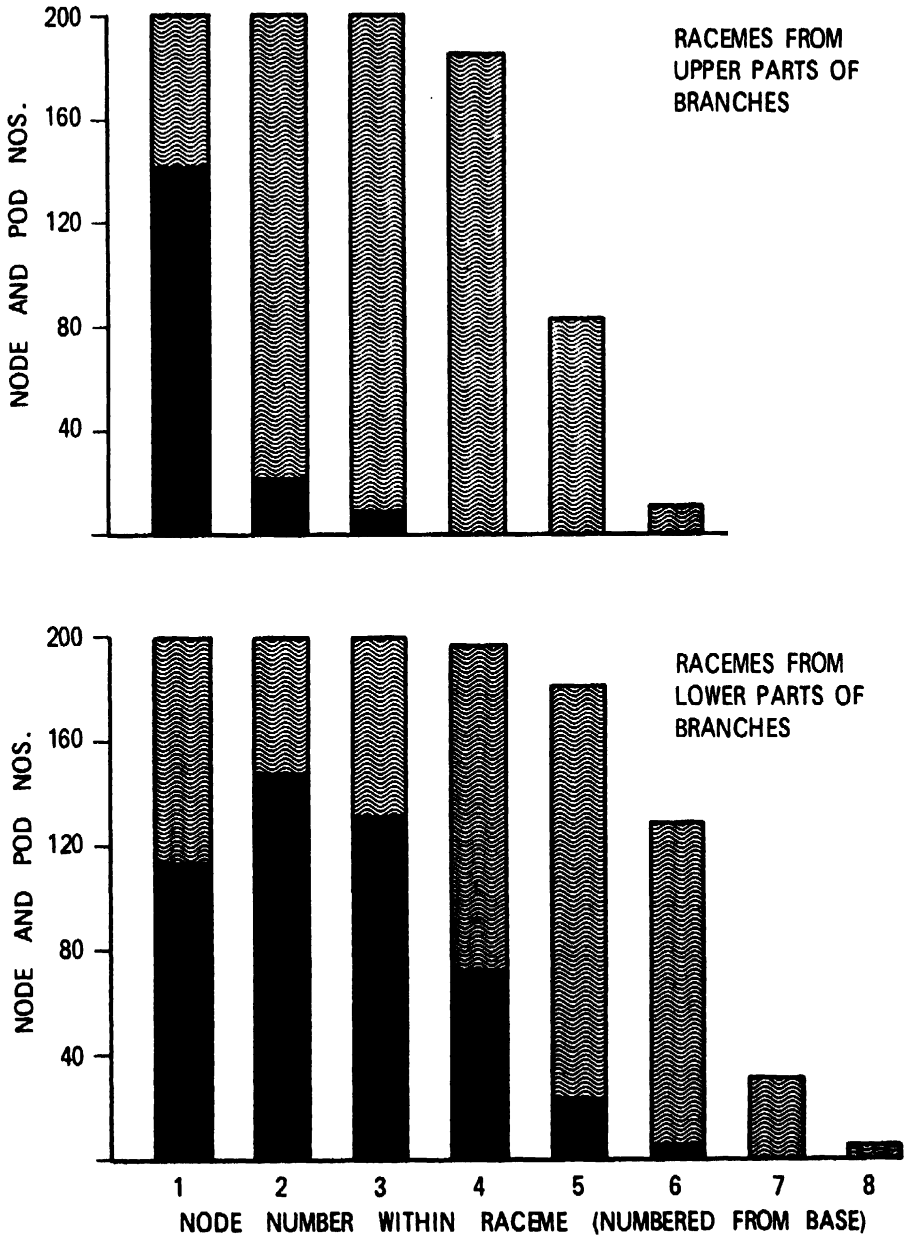
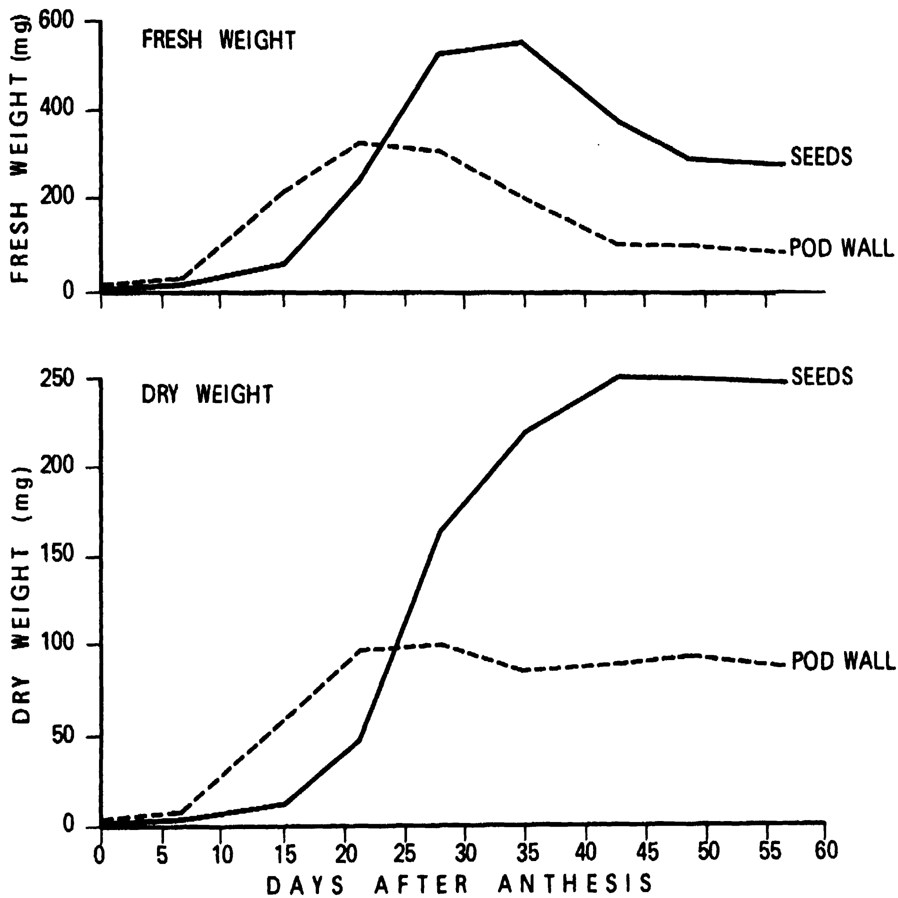


Figure 3. Development of pod wall and seeds in variety ICRISAT-1.



15 cm. Figure 6 gives representative results of root system development of JG 62. Root development continued in lower layers after flowering started; where we removed flowers to prevent pod development, the root development was more extensive and continued for a longer period.

Nodules

Weekly core samples also provided materials for analysis of nodulation. Samples in the top 15 cm of the black soil accounted for 99 to 100 percent of the nodules; some nodules were found in the 15 to 30 cm zone, but practically none were

Figure 4. Pigeonpea (ICRISAT-1): branch distribution after intercropping with setaria and soybean.

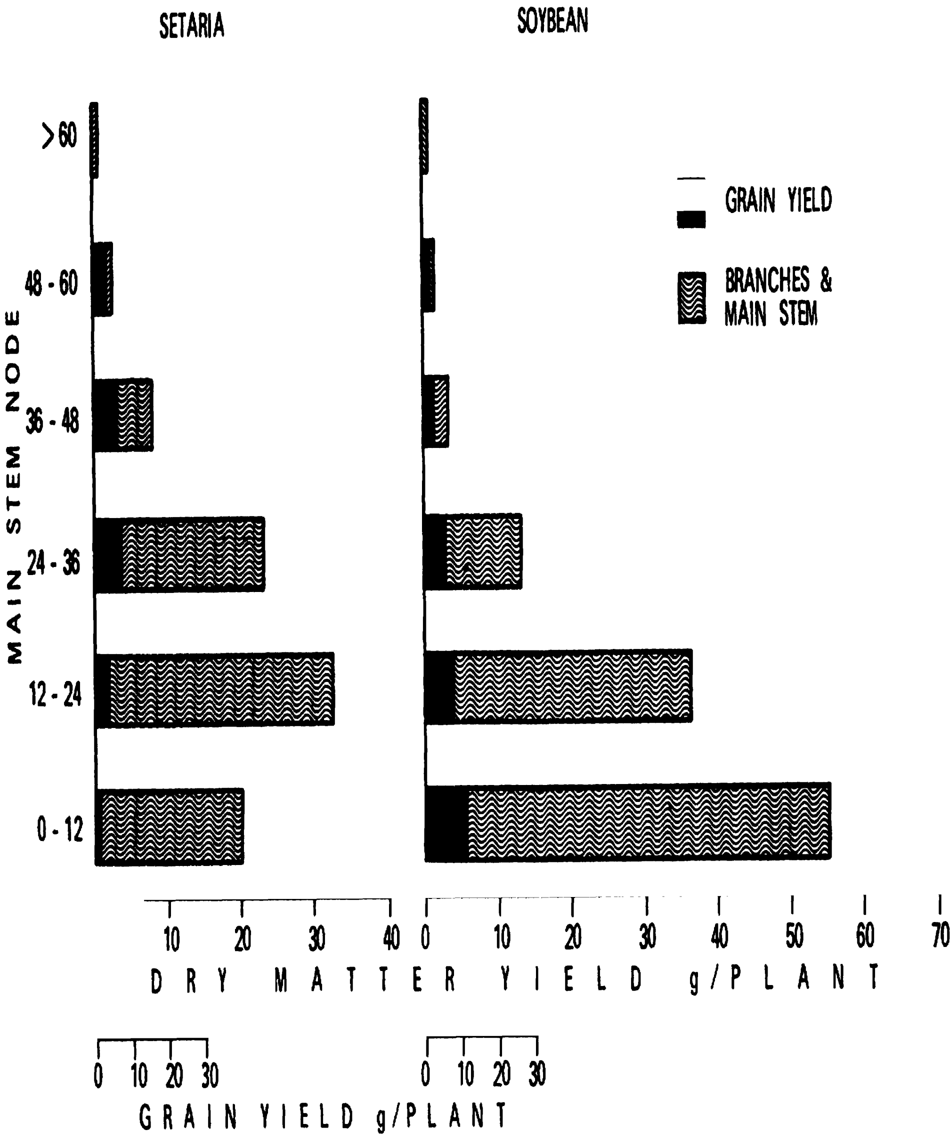


Figure 5. Increase in dry matter (leaf, stem and pod), leaf area index and pod number in chickpea varieties: (A) G-130 and (B) G 62/404 (1974-75).

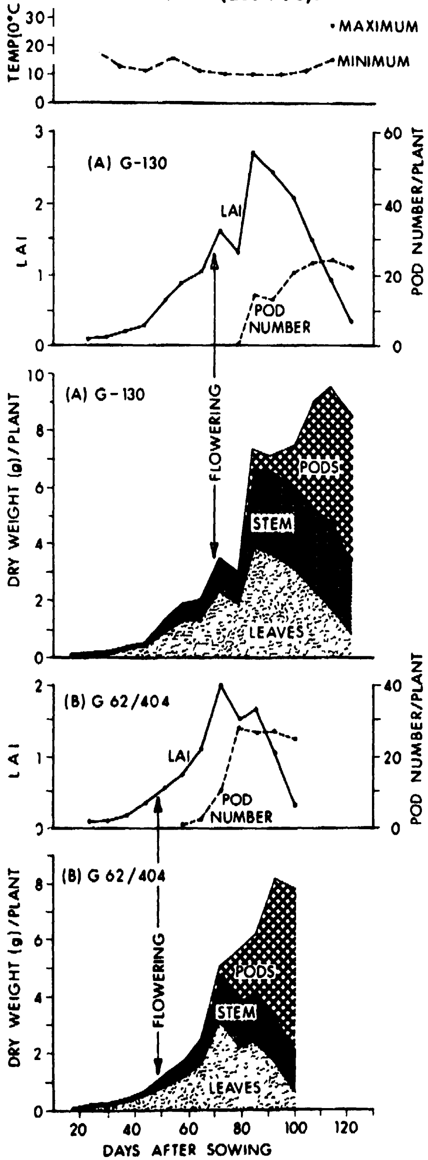
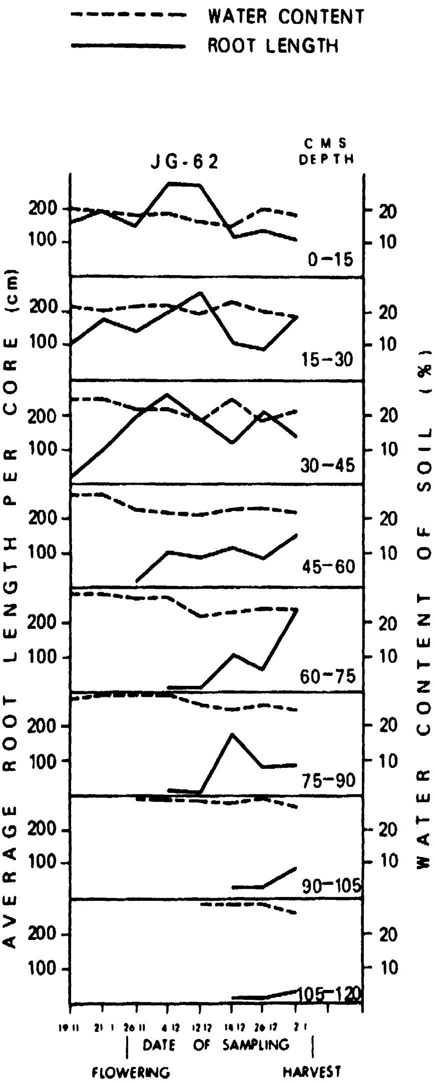


Figure 6. Root lengths and moisture percentage at different depths.



detected at a lower level. Maximum nodule weight of JG 62 plants occurred two weeks after the start of flowering and then declined In T 3 the decline coincided more or less with the onset of flowering When the development of pods was prevented by flower removal, nodule weights in creased for at least six weeks and then declined

Pod Development

We found similar patterns of pod development in all cultivars studied Figure 7 presents typical patterns, with data on 850-3/27 Cultivars differed in rate of pod development and in the time required for maximum dry matter accumulation in the pods Pods of smaller seeded cultivars tended to reach physiological maturity earlier

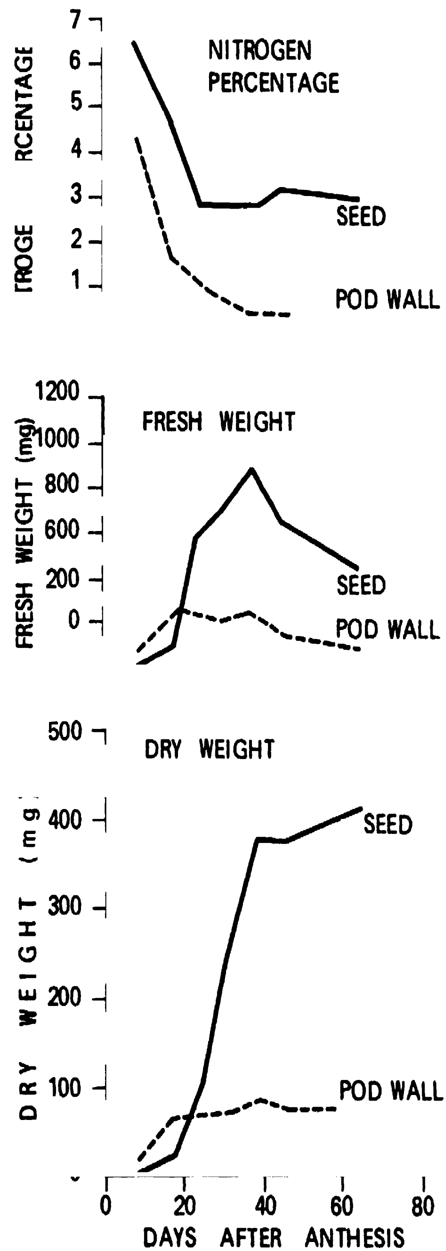
Plant Density and Planting Geometry

We gathered yield data on two cultivars, each at two plant populations and two planting configurations We also investigated yield results with radial plantings diverging from a central point to a distance of 0 75 m between radii at the periphery — plant populations varied in this case from 13 to 345 plants per m²

Geometry of the planting did not cause a significant difference at 50 plants per m², nor did varieties perform significantly differently at those population levels At 33 plants per m², however, the rectangular pattern was significantly better than square The cultivars Chaffa and BEG 482 were grown at three populations, 33, 50 and 100 plants per m² The yield for increase from 33 to 50 plants was 28 percent and from 33 to 100 plants was up 49 percent

In the radial configuration, per-plant yields at the lowest density of T 3 and 850-3/27 were seven to eight times greater than at the highest density The difference in Chaffa was only two-fold Yield per unit area, however, was greatest for the high-density The greater number of plants more than compensated for the lower yield per plant

Figure 7. Fresh and dry weight of different components of a developing pod in CV 850-3/27.



Pulse Pathology

Investigations into the pathology associated with pigeonpea and chickpea began toward the end of the monsoon season of the report year, in September 1974 With addition of the senior pathologist to the staff, attention focused on two diseases of pigeonpea — wilt and sterility mosaic virus — and the wilt complex in chickpea

Pigeonpea

Wilt symptoms appeared in pigeonpea plots in November, with symptoms more visible on black soil plots In January we examined the germplasm and breeding blocks, finding wilt in 500 lines Plants infected within those lines ranged from 1 percent to 100 percent prevalence Twenty-nine entries had 50 percent or more prevalence, with five showing over 80 percent Many lines showed no incidence of wilt in this screening

Resistance to major diseases is one goal in the ICRISAT breeding program To provide efficient means to assist breeders in this work, we initiated a wilt-sick plot which will have conditions that should produce 100-percent disease incidence in susceptible material

The plan for this 1 5 ha black soil sick plot is as follows (The first steps had been carried out by the end of this report period)

1 A composted mixture of chopped stubble of field-wilted pigeonpea, pod husk, and sorghum heads was scattered over the plot in early March The material was applied at a rate of 500 ft^3/ha and incorporated into the soil
2 A wilt-susceptible cultivar, Sharda, was planted at a rate of 14 kg/ha, after a month and a half, the plants will be chopped and worked into the soil
3 Another application of composted material (as in step 1) will be made in early May
4 In late June pigeonpea *Fusarium* will be added by incorporating 1 25 q/ha of sorghum grain that has been colonized by that disease
5 Additional inoculum will be added, and it is expected that the plot will be ready by kharif 1976

Much of our attention on sterility mosaic virus dealt with methodological problems of screening techniques, transmitting the disease in the laboratory and aspects of the virus-vector relationship We screened 455 pigeonpea cultivars, finding five that showed no symptoms of infection

Chickpea

Various factors are considered responsible for wilt in chickpea These include fungi, viruses, soil salinity or alkalinity, and moisture stress We are investigating this complex on a systematic basis, both at the research site and in other areas where chickpea is grown

In addition to recording detailed observations of dying chickpea plants during this first season, we carried out some additional analyses From wilted/dried plants we isolated *Fusarium oxysporum, F solani, Rhizoctonia bataticola, Operculella padwickii, and Sclerotium rolfsii* We also found two viral diseases tentatively named as chickpea stunt and chickpea severe mosaic

As our work progresses, we will probe deeply into this complex

Pulse Entomology

Pests of Pigeonpea

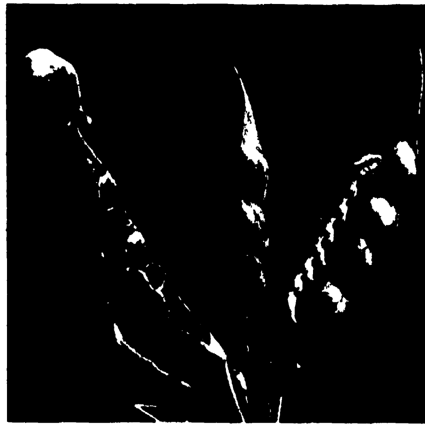
The scattered and sometimes scant entomological literature on pigeonpea pests did not provide a sufficient base for our work So we concentrated efforts on surveying and sampling growing crops to determine the species present and to evaluate their significance A specially isolated plot was planted to two cultivars of pigeonpea — ICRISAT 1 and T 21, and we sampled regularly

Among 60 pests of this crop, we found potentially important species of leaf roller, leaf tier, caterpillars, and potential vectors of plant pathogens on the young plants Pests threatening the plants in later growth included pod borers, plume moths, blues butterflies, pod fly, and weevil Stem fly was important in out-of-season crop

Damage and Loss

We carried out sampling on pigeonpea in various growing situations — sprayed and unsprayed, in breeders' blocks and in watershed cropping trials We found some apparent difference in pest damage between the early (T 21) and midmaturing (ICRISAT 1) cultivars On T 21, we found up to 46 percent of the buds and 35 percent of the flowers could be damaged late in the season with up to 60 percent of the pods damaged We observed less overall damage on the mid-maturity ICRISAT 1

There were two growth habits in plants of the earlier maturing cultivar One, which we designated "Ageti' type, was shorter and bore pods clustered at the ends of branches, it sustained more pod damage by lepidopterous borers — 68 percent The plants of "true" T 21 type showed 48 percent pod damage by the lepidopterous borers The damage by pod flies was the reverse 38 percent of the true T 21 type were damaged; 11 percent of the pods of the Ageti type were affected



H armigera *damaging pigeonpea pods*

The extent of damage on early pods was greater than on late pods, according to data provided from split pickings of the T 21 cultivar In more than 1,600 early pods, we found 86 percent showing lepidopterous borer damage and 18 percent pod fly damage In over 4,000 late pods, the comparable figures were 36 and 38 percent, respectively

The main pests were undoubtedly the leaf tier, *Eucosma critica* M, the plume moths, *Exelastis atomosa* W and *Sphenarches anisodactylus* W, the pod fly *Melanagromyza obtusa* Mall, and the pod borer, *Helicoverpa armigera* Hub

In Farmers' Fields

We're interested in the pest situation as it affects our target crops throughout the semi-arid tropics The experiment station site at Patancheru is only one limited eco-system We looked beyond our own borders in a small way, sampling pigeonpea pods from 30 farms within 200 km of the research farm Detailed examination of these pods disclosed considerable losses:

Site	% Damaged Pods	
	Borer	Pod Fly
Patancheru	23	9
Sangareddy	28	13
Sadashivapet	46	14
Zaheerabad	12	48
Vikarabad	19	33
Purgi	13	38

At all sites there was a significant field infestation by *Bruchids* amounting to between two and five percent.

Pests of Chickpea

Chickpea at our research site appears to be less favored by insects than is pigeonpea. We recorded only 18 insects in the observation plots — the cultivars C 235 and BEG 482 were sowed on black soil well away from other crops and out of range of spray operations.

Only four to five percent of pods of these cultivars were destroyed by the one serious pest we found, *Helicoverpa armigera.* There was some damage to young leaflets, but it was not severe. We found *Agrotis spp.* in small numbers. We observed that *Aphis craccivora* Koch could occur in large numbers on chickpea. The significance of this fact is that the insect might serve as an efficient disease vector.

We included chickpea in our samplings of fields of farmers up to 200 km from the Patancheru site. Chickpea is not widely grown in that area, and only nine samples were obtained. Damage to pods ranged from a high of 24 percent to a low of 3 percent, with most samples in the range of 10 to 17 percent.

A surprising observation came when we incubated chickpea samples from our own plots and from farmers' fields: we found no *Bruchid* beetles.

The limited range of insects attacking chickpea may be related to the highly acidic exudate produced by chickpea leaves. Samples have gone to the Centre for Overseas Pest Research in London, for testing. If it is found that there is an antifeedant effect, this might lead to developments in breeding for resistance or tolerance

Late instar larva of H. armigera *damaging a chickpea plant.*

Looking ahead in Legume Entomology

The first full year of entomological investigations on legume crops has underscored our need for a broader base of biological information on the pests concerned — the literature is scattered and incomplete. Attempts will be made to assess factors favoring attack and pest population increase in sole crop and intercrop situations in SAT environments. Contacts have been established with the All-India Coordinated Pulse Improvement Project and joint trials to assess the possibilities of locating resistances in the target crops will be carried out.

FARMING SYSTEMS

- Production Factor Research
- Resource Utilization Research

Farming Systems

Low yields and unstable production year-to-year characterize the agriculture of the semi-arid tropics These two characteristics focus ICRISAT's goals for its farming systems research We approach from two main orientations one on resource utilization and conservation, with particular concern for water, which is generally considered the most limiting factor, the other on factors of production, such as tillage and planting methods, irrigation, cropping systems, fertilization, and use of implements

The agriculture of the semi-arid tropics is typically carried on by small farmers with few implements, little capital, and limited willingness or ability to take risks The central goal for many must be to provide food for the immediate family Farming methods developed over the centuries have emphasized techniques and varieties that tend to assure some crop in the worst of times even though there is promise only for a fair crop in the best of times

Recognizing the centuries-old constraints on the farmer of the semi-arid tropics, we approach the research task as one of improving on the methods of the contemporary farmer We seek improvement within the framework of existing circumstances We concentrate on realistic approaches that can be applied by many farmers with little risk It is a painstaking job of first building an understanding of the factors of soils and crops performance under the conditions of the semi-arid tropics and then making changes that are feasible and have a visible impact on the levels and stability of production Fortunately, talented researchers have been at work on these matters for some years In ICRISAT we have the means to carry their work across a wider front, to work on more approaches simultaneously and to use the international network to test ideas under differing conditions

Production Factor Research

A host of interrelated variables come together in the production of plants anywhere in the world The person who would intervene in that complex production process must have the best possible knowledge There is much to be observed and verified by researchers seeking to improve production under the conditions of the semi-arid tropics Our program at ICRISAT draws on work of others and seeks systematically to fill in important knowledge gaps

We do not attempt to describe or report on all of our observations and experiments with production factors Rather we have selected some of the work where the 1974-75 year saw the start of new work or added importantly to the work begun earlier

Intercropping

Climatic conditions in the Hyderabad area often provide potential for double cropping But timely land preparation and planting may be difficult under the conditions in October or November when the kharif, or monsoon-season, crop has been taken off, and when the soil rapidly changes from too wet to too dry Pigeonpea as an intercrop offers a way to get two crops into the ground, since it can be planted at the same time as the other crop Pigeonpea is a slow-starter, when its companion is ready for harvest, pigeonpea is ready to begin its major growth

This year brought our third round of intercropping studies on pigeonpea We have investigated several patterns of intercropping sole planting, alternate rows, and alternate rows at different spacings We again used three patterns studied in earlier years 45-cm rows planted in four rows of the same crop and then four rows of the other, alternating single rows of each crop 45 cm apart, and a thicker rate with a pair of rows of the companion crop 22 5 cm apart then a single row of the intercrop Another spacing was added this year, which simulates the spacing in ridge-and-furrow plantings one row of each crop 25 cm apart with a 50-cm interspace before the next pair of rows

Again this year the value of intercropping came through strongly Results in the following

Intercropping Experiments Pigeonpea-Cowpea shown in the foreground First eight rows are alternate row plantings and the second set of eight rows represent sole planting of pigeonpea and cowpea

tables are presented in economic value of the grain crops produced, expressed in rupees per hectare They give striking evidence of the greater value produced by two crops sharing the same land area

Ratooning

Both pearl millet and sorghum can be ra tooned under the conditions at the Hyderabad experiment station Significant regrowth occurs after either a cutting for grain or a cutting for fod der Investigations reported last year indicated generally that grain production is maximized when the crop is permitted to make a grain crop before harvesting

In 1974 75 we took a deeper look into the ra toonability of some of the leading pearl millet and sorghum varieties We found significant dif ferences in performance under the two ratooning systems applied (1) fodder harvest followed by a grain crop from regrowth and (2) a system of grain harvest green stalk removal then a second grain harvest and green stalk removal However the yield levels were generally too low and we are screening for genotypes which have better regrowth after an early harvest Tables 22 and 23 set out the results

Fertilization

Response patterns of our first two years of fertilizer experiments appeared again in the 1974 season Significant increases in grain yield occurred for both nitrogen and phosphorus on sorghum, pearl millet, and sunflower in both red and black soils Maize in black soils showed

The response of maize to nitrogen application on black soils. The yield with no nitrogen and 120N was 3.4 and 41.7 q/ha, respectively.

Table 20. Value of grain produced under four patterns of intercropping on black soils. Hyderabad 1974-75.

Intercrops	Sole Crop 45 cm rows	Alternate 45 cm rows	Alternate 25 cm rows 50 cm space	Alternate 22.5 cm pair 67 cm space
		— Rupees per hectare —		
Cowpea-Pigeonpea	3 640	4 100	5 290	5 080
Cowpea	620	680	620	1 080
Pigeonpea	3 020	3 420	4 670	4 000
Setaria-Pigeonpea	5 810	4 900	7 280	7 250
Setaria	2 510	2 100	2 380	3 060
Pigeonpea	3 300	2 800	4 900	4 190
Pearl Millet-Pigeonpea	6 680	5 530	7 490	8 770
Pearl Millet	4 380	3 720	5 150	6 900
Pigeonpea	2 300	1 810	2 340	1 870
Sorghum-Pigeonpea	6 280	6 330	10 300	9 180
Sorghum	4 090	4 620	8 200	7 450
Pigeonpea	2 190	1 710	2 110	1 730

Cultivars: Cowpea, C 152; Setaria, H 1; Pearl Millet, HB 3; Sorghum, CSH 5; Pigeonpea, Hy 3A

Table 21. Value of grain produced under four patterns of intercropping on red soils. Hyderabad 1974-75.				
Intercrops	Sole crop 45 cm rows	Alternate 45 cm rows	Alternate 25 cm rows 50 cm space	Alternate 22 5 cm pair 67 cm space
		— Rupees per hectare —		
Cowpea Pigeonpea	3 340	4 590	4 650	4 690
Cowpea	600	320	620	660
Pigeonpea	2 740	4 270	4 030	4 030
Setaria Pigeonpea	3 780	5 470	6 190	6 990
Setaria	1 270	1 150	1 120	1 740
Pigeonpea	2 510	4 320	5 070	5 250
Pearl Millet Pigeonpea	5 270	7 100	6 990	8 090
Pearl Millet	2 440	4 000	4 210	4 840
Pigeonpea	2 830	3 100	2 780	3 250
Sorghum Pigeonpea	5 940	7 010	7 880	6 950
Sorghum	3 110	2 870	3 880	4 090
Pigeonpea	2 830	4 140	4 000	2 860

Cultivars Cowpea C 152 Setaria H 1 Pearl Millet HB 3 Sorghum CSH 1 Pigeonpea Hy 3A with Sorghum ICRISAT 1 with other crops

similar response In this latter case, an additional dressing of nitrogen in August to overcome nitrogen deficiency boosted yield to 45 q/ha

Potassium has not shown a yield benefit in our trials Typically the top yield has come with a treatment of 120 kg/ha of nitrogen and 25 kg/ha of phosphorus When nitrogen deficiency symptoms appeared on the maize in black soil, the added 40 kg/ha produced a further response

A new study this year focused on the nitrogen uptake by plants We analyzed five crops for percentage of nitrogen in whole plant seedlings 25 days after planting Table 24 reports the findings

Supplementary Water

Dry periods in the monsoon are typical of the semi arid tropics, even when normal or above-normal seasonal rainfall occurs The result is usually a reduction of crop yield especially on the red soils which have relatively low water-holding capacity Thus availability of water for supplemental irrigation should be an important means to reduce risk and increase production

We have investigated 'lifesaving' supplemental irrigation during three monsoon seasons at ICRISAT Studies in 1974 included water added to sorghum maize, pearl millet and sunflower Four treatment strategies were devised and carried out (1) no supplemental water, (2) one application of 5 cm of water at one critical moisture stress period, (3) two applications of 5 cm each at critical moisture stress periods, and (4) normal irrigation when water depletion reached 50 per cent Two rates of nitrogen fertilizer were included in the design — 58 and 120 kg/ha respectively

Table 25 reports the results

Table 22. Performance of eight sorghum cultivars on black soil under two systems of ratooning. Hyderabad 1974.

Cultivars	Harvested Oct. 7		Harvested Nov. 15	
	Grain q/ha	Green stalks q/ha	Grain q/ha	Green stalks q/ha
Grain — Grain System				
CSH 1	47.5	178	0.8	8.7
CSH 3	43.8	261	1.1	5.8
CSH 5	54.6	298	1.3	5.8
21 E	59.3	201	1.3	7.9
22 E	62.7	195	1.3	4.5
23 E	59.5	190	1.3	7.9
24 E	51.8	215	1.2	5.8
Local	45.1	211	1.1	3.3
LSD (05)	13.4	50	0.4	2.3

Fodder — Grain System	Harvested Aug. 24	Harvested Nov. 15	
	Green fodder q/ha	Grain q/ha	Green stalks q/ha
CSH 1	165	1.7	48
CSH 3	265	1.5	62
CSH 5	325	1.4	48
21 E	198	2.7	82
22 E	230	2.6	55
23 E	226	2.7	65
24 E	265	2.5	70
Local	168	1.0	37
LSD (05)	61	1.0	24

The same experiment was designed and planted on black soils. However, all treatments were applied only to maize and sunflower. In those crops we measured a significant response to nitrogen fertilizer but not to supplemental irrigation. A single 5-cm irrigation was applied to sorghum under the 50-percent depletion condition; it did not produce a significant increase, although the increase for nitrogen fertilizer was significant. No irrigation treatment was justified for pearl millet; nitrogen fertilizer produced a significant increase on this species too.

The black soil phase of the experiment could not be carried out fully because the moisture stress did not reach critical levels due to the higher water-holding capacity of the black soils.

Relay crops were grown on these plots following harvest of the kharif plantings. Sorghum was grown following sunflower in both red and black soils; average yields were, respectively, 20.5

Table 23. Performance of eight pearl millet cultivars on black soils under two systems of ratooning. Hyderabad 1974.

Cultivars	Harvested Sept 18		Harvested Nov 15	
	Grain q/ha	Green stalks q/ha	Grain q/ha	Green stalks q/ha
Grain — Grain System				
HB 3	39 8	133	3 7	2 9
Early Composite	48 5	143	3 9	7 5
Medium Composite	25 8	152	1 9	9 6
Late Composite	30 7	128	2 2	18 3
Dwarf Composite	27 5	128	1 5	7 9
J 1270	26 2	71	1 2	6 3
J 1644	32 3	81	2 1	2 5
Local	20 0	96	1 9	2 5
LSD (05)	5 7	24	1 2	5 0

Fodder — Grain System	Harvested Aug 21	Harvested Nov 15	
	Green fodder q/ha	Grain q/ha	Green stalks q/ha
HB 3	170	8 2	25
Early Composite	228	5 5	24
Medium Composite	218	8 0	39
Late Composite	275	5 8	67
Dwarf Composite	236	4 2	46
J 1270	136	5 5	14
J 1644	226	5 5	27
Local	225	4 3	23
LSD (05)	NS	NS	14

and 10 3 q/ha, with no significant differences due to the effect of earlier treatments Chickpea was planted in relay behind maize, returning yields of 1 2 q/ha in red soil and 9 1 q/ha in the black No significant differences were due to the earlier season treatments

Inoculation

The nitrogen-fixing ability of legume plants has special value for the limited-resource farmer of the semi arid tropics When a new legume is introduced from another area, it may be necessary also to introduce the appropriate in oculum to assure nitrogen fixation This year we investigated inoculation of soybeans and chickpeas, comparing both nodulation and yields related to different inoculums and nitrogen fertilization

Inoculation produced measurable increases in nodulation on both crops, but the yield dif ference was significant only with soybeans Ta ble 26 displays the grain yield results

Table 24. Effect of fertilization on nitrogen content of seedlings 25 days after planting. Hyderabad 1974.

Treatment	Percentage nitrogen in whole seedling				
N P K (kg/ha)	Sorghum	Pearl millet	Sunflower	Castor bean	Maize
— Red Soils —					
0 25 0	2 85	2 96	2 93	2 75	
40 25 0	3 96	3 75	3 87	4 50	
80 25 0	4 70	4 11	4 20	4 56	
120 25 0	4 54	3 94	4 37	4 60	
120 0 0	3 98	3 94	4 15	4 42	
120 25 50	4 63	4 20	4 40	4 75	
— Black Soils —					
0 25 0	1 72	2 18	1 86		1 53
40 25 0	3 74	4 67	4 20		4 42
80 25 0	4 02	4 81	4 25		3 94
120 25 0	3 73	4 54	3 92		4 07
120 0 0	3 57	4 40	3 88		3 68
120 25 50	4 14	4 73	4 24		4 54

Chickpea Management

Chickpea has been the subject of relatively little careful and controlled observation In the 1974-75 season we studied date of planting, row spacing and depth of planting In earlier seasons we had seen what appeared to be an advantage for mid September or early October planting, so we established an experiment to test the effect of date of planting Table 27 reports the results of that experiment, indicating that even earlier planting had yield advantage in this season Cultivars did not differ significantly by planting date, but that outcome may have been due to outstanding overall performance by one early cultivar, G-62-404, regardless of the time of planting

Chickpea is credited with ability to emerge from deep planting situations, this quality is important in permitting planting in rough, relatively dry seedbed after a kharif crop has been removed We studied emergence and yield of chickpea at four planting depths on both red and black soils Differences were not significant in either set of trials

Row-spacing trials disclosed no significant difference when two cultivars were planted at four spacings These plots were grown in black soil under non-irrigated conditions

Rooting Pattern

Depth and distribution of roots directly affect a plant's ability to withstand drought Last year we began studies of roots of seven major crops grown in our principal soils In the current period these studies continued, involving eight crops grown on black soils and six grown on red soils

The research procedure involved machine-collected core samples of 7 6 cm diameter taken at 15 cm increments in red soils and 30 cm increments in black soils Three samples were taken

Table 25. Effects of supplemental irrigation and nitrogen fertilizer on grain yields of four crops grown on red soils. Hyderabad 1974.

Crop and Nitrogen Rate	Water treatments — Yields in kg/ha				Nitrogen means
	None	One 5 cm	Two 5 cm	At 50% depletion	
Sorghum 58 kg/ha	23 0	23 6	23 0	27 5	24 3
120 kg/ha	32 2	42 1	54 4	48 8	44 4
Irrigation means	27 6	32 9	38 7	38 2	
Significance	Irrigation means, LSD (05) = 4 4 Nitrogen means, LSD (05) = 3 2 Interaction, LSD (05) = 6 3				
Maize 58 kg/ha	35 3	37 0	41 7	39 7	38 4
120 kg/ha	46 3	52 4	58 3	56 7	53 4
Irrigation means	40 8	44 7	50 0	48 2	
Significance	Irrigation means, not significant Nitrogen means, LSD (05) = 6 1 Interaction, not significant				
Pearl Millet 58 kg/ha	19 6	21 7	27 9	29 6	24 7
120 kg/ha	38 1	35 6	31 0	35 7	35 1
Irrigation means	28 9	28 7	29 5	32 7	
Significance	Irrigation means, not significant Nitrogen means, LSD (05) = 4 7 Interaction, not significant				
Sunflower 58 kg/ha	6 1	6 8	6 7	6 8	6 6
120 kg/ha	6 8	8 0	8 4	11 1	8 6
Irrigation means	6 5	7 4	7 6	9 0	
Significance	Irrigation means, LSD (05) = 1 7 Nitrogen means, LSD (05) = 0 8 Interaction, LSD (05) = 2 0				

in each field for each crop The soil and root samples were washed to separate roots, and measurement consisted of the composite length of roots taken in each sample

Tables 28 and 29 present the results of the current samples Data are displayed as percentage of total root lengths of a given crop by the respective depths

In black soils, only chickpea, setaria, and chillies failed to send roots to the 180-cm zone (The 1974 samplings found chickpea roots at this lower zone, however, this year's samplings at that depth encountered the murram layer, which was apparently not penetrable by chickpea this year) Among the crops sampled, safflower put the most roots into the lowest zone, setaria — as last year — was the most shallow-rooted

In red soils, sorghum was found to have the deepest rooting pattern, with pigeonpea ranking next The most shallow rooted — those with the highest percentages of roots in the top 30 cm — were tomato, sunflower and pearl millet The murram layer was also encountered under the red soils, and that affects the rooting pattern. We will look into rooting pattern of these crops where there is no factor such as murram to impede root penetration.

Table 26. Effect of inoculants and nitrogen fertilizer on the yield of soybeans on red soils. Hyderabad 1974.

Inoculant	Nitrogen rate kg/ha	Grain yield q/ha
Pantnagar	0	9.4
Nitragin	0	14.5
None	0	9.7
None	40	12.2
None	80	16.3
None	120	12.5
LSD (05)		4.6

Seedling Survival Under Moisture Stress

The black and red soils of the ICRISAT site — and in many other semi-arid tropic locations — present special challenges to getting the seed in the ground and growing. The lighter red soils are relatively easy to work when relatively dry; if seed is planted in dry soil, a light rain may quickly infiltrate and cause germination but not provide enough moisture to sustain growth. On the other hand, when completely dry, black soils are almost unworkable with the farmer's tools and power source; but if worked immediately after the harvest of the previous crop, seed can be put into dry soil to await enough moisture both to germinate and start the young plants — a light rain won't reach the seed. However, we found in a simulation analysis, based on 70 years of Hyderabad rainfall data, that there is substantial risk involved in dry planting once or twice every ten years.

The 1974 season let us observe the problems involved in planting in anticipation of the start of the monsoon rains. Sorghum and pearl millet were planted on two black soil watersheds that

Table 27. Effect of planting date on yield of three chickpea cultivars of early, medium and late maturity on black soils. Hyderabad 1974-75.

Date of planting	Cultivar and Maturity — Yields in q/ha			
	G 62 404 Early	T 3 Medium	G 130 Late	Mean
August 29	11.3	12.2	12.3	11.9
September 10	8.3	12.3	10.2	10.3
September 24	8.8	10.6	13.0	10.8
October 8	13.4	8.2	8.6	10.1
October 22	9.3	5.8	7.5	7.5
November 5	9.8	4.7	5.7	6.8
Cultivar mean	10.2	9.0	9.6	

Significance: Dates, LSD (05) = 3.0
Cultivar, not significant
Interaction, LSD (05) = 3.3

Table 28. Depth and distribution of roots of eight crops grown on black soils — expressed in percentage by depth increments. Hyderabad 1975.

Crop	Depths in centimeters at which samples were taken					
	0-30	30-60	60-90	90-120	120-150	150-180
Sorghum	49.4	18.1	15.4	11.4	3.5	2.2
Safflower	32.5	15.1	21.9	16.5	10.8	3.3
Sunflower	69.1	9.2	13.6	5.3	1.7	1.1
Cotton	38.8	28.7	23.8	5.6	2.4	0.7
Chickpea	28.1	27.0	37.2	7.7	-0-	-0-
Pigeonpea	49.5	16.9	18.3	8.9	5.2	1.2
Setaria	47.5	28.4	19.3	4.4	0.5	-0-
Chillies	72.6	14.7	8.9	3.0	0.8	-0-

Table 29. Depth and distribution of roots of six crops grown on red soils — expressed in percentage by depth increments. Hyderabad 1975.

Crop	Depths in centimeters at which samples were taken					
	0-30	30-60	60-90	90-120	120-150	150-180
Sorghum	35.4	13.5	19.4	15.9	14.1	1.7
Pearl Millet	64.0	15.6	12.1	6.0	1.7	0.6
Sunflower	64.5	20.2	10.8	3.6	0.9	-0-
Pigeonpea	35.6	28.9	19.2	11.8	4.5	-0-
Castor	46.7	27.8	16.9	6.1	2.6	-0-
Tomato	80.9	12.2	4.0	3.0	-0-	-0-

include some sandy, gravelly areas — not unlike the red soils in water-holding ability. These light areas were surrounded by the typical heavy black clay soil. Planting was done early in June, anticipating a normal arrival of monsoon. However, only light showers occurred until late in the month. On June 15 and 16 light showers resulted in 17 mm of rain on these plantings.

Penetration of the small amount of rain had reached the 4- and 6-cm depth at which sorghum and pearl millet seeds had been planted in the light soil. The sorghum planted at the same depth in typical black soils was not reached, so no germination took place. (Pearl millet, which was planted at a more shallow depth, was germinated in both the heavy and light soils, and many seedlings died for lack of sustaining moisture.)

Where maize germinated from this small amount of moisture, wilting was soon observed. In the next five days with no rain, wilting became more pronounced. During this period — June 20 through 25 — we applied water to small areas to observe recovery time. On June 21, wilted plants recovered within 15 minutes of the application of water. But subsequent recovery times grew longer: June 23, 35 minutes to recovery; June 24, 60 minutes; June 25, 72 minutes.

Substantial rains began on the night of June 25, and all wilted sorghum and maize plants recovered. Those same rains then brought the germination of sorghum and maize that had lain in the dry black soil since planting weeks earlier. The resulting stands were satisfactory, except where rats had robbed seed from the ground.

To summarize our observations, we noted that sorghum and maize showed ability to survive under severe moisture stress. Pearl millet was notably less able to survive under similar conditions. We can offer the tentative suggestion that sorghum and maize planted at a depth of 6 cm offer considerable flexibility in adjusting to erratic moisture conditions often characteristic of the early monsoon in our region.

Genotype Evaluation

Five major crops are the focus of ICRISAT's principal emphasis in crop improvement. Many additional species are important to farmers in the semi-arid tropics, however. We have included many of these other crops in farming systems research. In the 1974-75 year we carried out small-scale genotype evaluation of 11 crops. Here is a summary with some pertinent observations:

Black Gram *(Phaseolus mungo)* — 14 cultures.

Yield range for two pickings, 7 to 11 q/ha. All showed bud necrosis; most showed leaf spot infection and collar rot.

Cowpea *(Vigna sinensis)* — 40 cultures.

Yield range, 0.33 to 12.2 q/ha. Relatively free of diseases.

Mungbean *(Phaseolus auerus)* — 40 cultures.

Severe disease attacks — yellow mosaic, bud necrosis, leaf crinkle, bacterial leaf spot and powdery mildew. Yield range, 1.33 to 4.38 q/ha for 28 cultures analyzed.

Soybean *(Glycine max)* — 69 cultures.

Yield range, zero to 17 q/ha. Nodulation poor to none due to ineffective inoculant or no native Rhizobia. Diseases found included bud necrosis, Rhizoctonia, mosaic and bacterial leaf spot.

Castor Bean *(Ricinus communis)* — 24 cultures.

Five cultures yielded above 25 q/ha from six or seven pickings; 44 to 51 days to flowering and 93 to 116 days to first picking. Infestation of semi-looper in most lines.

Groundnut *(Arachis hypogea)* — 10 cultures.

Yield range, 3.3 to 11.3 q/ha. All susceptible to Cercospora leaf spot. Also observed general yellowing; a virus or micronutrient deficiency suspected.

Sesame *(Sesamum indicum)* — 18 cultures.

Highest yield, 7.2 q/ha. Maturity range, 100 to 115 days.

Sunflower *(Helianthus annuus)* — 8 cultures.

Yield range, 10.5 (Mordan 1267) to 14.9 q/ha (Sunrise Selection). Early maturing Mordan 1267, 90 days, may fit for relay cropping with a late maturing crop. Four Rumanian and three local cultivars also grown — 2.6 to 5.9 q/ha yield, with *Rhizoctonia solani* observed in all.

Cotton *(Gossypium sp.)* — 13 cultures.

Yield range, 4.8 to 20.1 q/ha. Days to picking, 130 to 167. Heavy infestations of jassids and heliothus.

Triticale

Trial is part of All-India Coordinated Program — six replications in 6 by 6 triple lattice design, with three irrigations. Highest yield, 16.1 q/ha recorded for JNK 6T-192. All cultures matured between 96 and 104 days.

Wheat *(Triticum aestivum)* — 25 cultures.

Uniform regional trial with low fertility and rainfed conditions. Yield range, 9.5 to 12.6 q/ha.

Safflower *(Carthamus tinctorium)* — 20 cultures.

Another 140 lines grown in non-replicated observation plots. All lines screened for rust (6 lines resistant, 95 had trace to moderate reaction, 65 were susceptible) and *Rhizoctonia* root rot (22 were resistant and the rest susceptible) One line, 985, was resistant to both pathogens

Farm Equipment and Tools

Humans and animals are the primary source of power for most farms in the semi-arid tropics That will be true for a long time to come Therefore, in the ICRISAT Farming Systems improvement program, we will direct efforts toward more efficient use of draft animals and more efficient animal-drawn machinery We used tractor power extensively in getting operations established on the research site By the 1974 kharif season, however, we turned to animal power as the primary source for land preparation, planting and cultivation in the watershed based research

During the year we adapted several existing machines and tested them in the field These included

- Animal-drawn scraper that aids in such land development operations as gully reclamation, land smoothing, construction of terraces and waterways, and water storage facilities
- Seed-cum-fertilizer drill An Indian model drill was modified for work with our ridge-and-furrow system Major changes were made in the fertilizer distribution mechanism
- Relay planter for sowing a post-monsoon crop while the monsoon crop is still growing We are adapting an available planter mechanism so both planting and fertilizer application can be done in one pass through the standing crop
- Ridger and multiple-use tool carrier We are working with a British Kenmore tool carrier to develop a ridger with better performance A single furrow-opener drawn by a pair of bullocks has not been adequate With the modified machine, which prepares two ridges at a time, we worked up ridges immediately after harvest of the monsoon crop The machine gave us better alignment of ridges, since one furrow-open runs in a furrow made on the previous pass Also, we save considerable time, since we re making two ridges at a time instead of the single ridge with the earlier equipment
- Water tankers of 800 to 1,300 liters capacity One bullock can pull these small tankers We find them useful for such uses as irrigating fruit trees, delivering water for compacting the bund core in tank construction, and providing drinking water for people and animals at scattered work sites

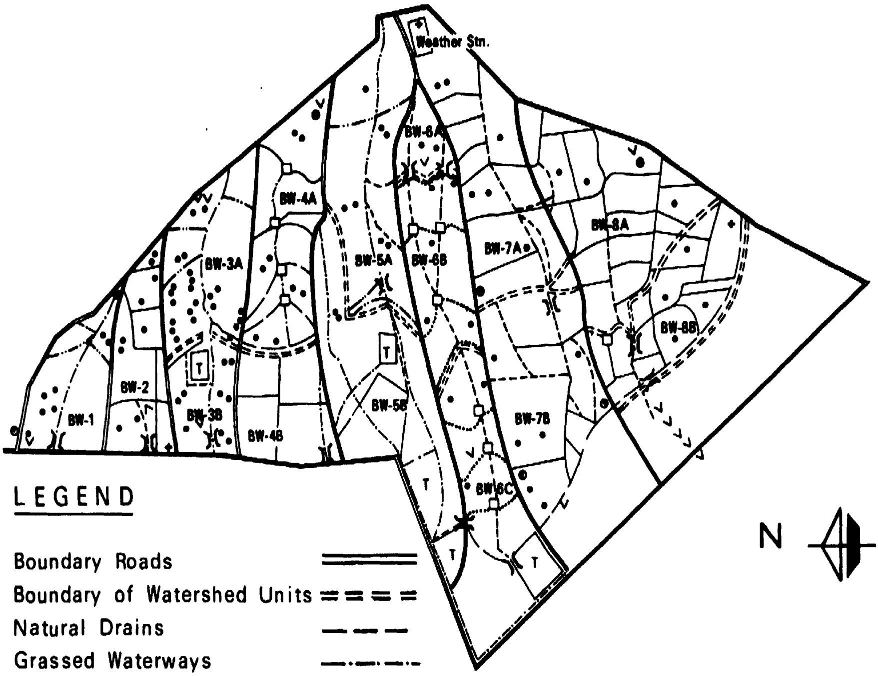
Animal-drawn ridger in operation during the early dry season This basic farm tool can also be fitted with a seeder, plow *or* cultivator.

Resource Utilization Research

Water is regarded as the most limiting factor in crop production in the semi arid tropics The amount of rainfall is limited — often occurring in high intensity — and only part of that rainfall enters into the processes of the growing plant That lost as evaporation or runoff during and after precipitation does not contribute to plant growth, nor does that lost by percolation into the groundwater below the plant root zone

As we seek improvements in resource use under the semi-arid conditions at ICRISAT, we set best use of all available water as a central objective We have chosen the small watershed, a natural catchment and drainage area, as the focus for study and intervention Within the watersheds we are investigating different cropping systems and different resource management technologies, from traditional to improved In this report year most of our watershed studies

Map of black soil watersheds BW-1 to BW-8.



LEGEND

Boundary Roads	═══
Boundary of Watershed Units	= = = =
Natural Drains	— — —
Grassed Waterways	—·—·—
Guide Terraces	—··—··—
Graded Terraces	—— ——
Field Bunds	———
Contour Bunds	....
Parshal Flume	
Outlet Structure	V
Non-Recording Rain Gauge	□
Neutron Probe Access Tube	⊙
Recording Rain Gauge	•
Piezometer Tube	+
T = Tank	

SURFACE AREAS OF WATERSHED UNITS

BW-1	3.5 HA	BW-6A	1.5 HA
BW-2	3.5 HA	BW-6B	4.2 HA
BW-3A	4.3 HA	BW-6C	4.3 HA
BW-3B	2.3 HA	BW-7A	8.7 HA
BW-4A	5.1 HA	BW-7B	6.6 HA
BW-4B	3.6 HA	BW-8A	8.1 HA
BW-5A	6.9 HA	BW-8B	5.1 HA
BW-5B	6.6 HA		

were carried out on eight black soil sites. Two red soil watersheds were available for studies this year, and more are being developed for future use.

Effective Rainfall

The 1974 monsoon season rainfall on the catchment areas was about 810 mm, a relatively high amount. We measured effective rainfall (i.e., the relative monsoon rainfall contributing to evapotranspiration). on three watersheds, each with different cropping systems.

We double-cropped on ridges and applied improved technology (fertilizer, pesticides, grassed waterways, improved implements) in one area. We used about 73 percent of the rainfall through the crop under those conditions. Of the total available, 116 mm was lost in runoff, about 100 mm percolated into the groundwater, leaving 590 mm for the crop.

Another black soil watershed was cropped with the same system. It had a runoff figure of 133 mm; however, 75 mm of that was collected in a storage facility within the watershed. About a third of that amount was lost through surface evaporation and losses in conveyance to irrigate, but still 50 mm was available from that storage. After deducting 100 mm that went to the groundwater, we found that this system had provided an effective rainfall of about 80 percent.

A third black soil watershed was fallowed during the monsoon and then flat-planted, with the same improved technology applied for the dry season crop. Runoff on this watershed amounted to 183 mm, about 150 mm was lost to groundwater, and more than 200 mm by evaporation from the bare soil. This system added about 200 mm of moisture to the soil that was used by the crop grown after the monsoon. Effective rainfall in this case was less than 30 percent.

Rainfall and Runoff

The 1974 monsoon at Hyderabad was unusual in several respects. It began relatively late, with the first major rainfall coming on June 27 — as a storm that dropped 75 mm of rain, reaching an intensity of 53 mm per hour. That intensity would be expected once in 10 to 20 years. On October 16, near the end of monsoon, a storm of even greater intensity (62 mm per hour) brought 90 mm of rainfall. Also, the 1974 monsoon's 810 mm total precipitation was well above the longterm average.

Thirteen experimental watersheds were ready for studies ahead of the 1974 monsoon. We obtained rainfall and runoff data from 11 black soil catchments — ranging in size from 1.5 to 6.9 ha — and on two red soil areas, one a 3.4 ha cropped area and the other a grazing site of more than 29 ha. Management systems applied included grazing with no land operations, monsoon fallow, mulching, flat-planting with contour bunds and with traditional boundary bunds, and ridge-and furrow planting on graded slopes of 0.4, 0.6 and 0.8 percent.

(Tanks for storage of runoff have been developed in several of these small catchments. The stored water is considered as runoff in this instance, since measurements here deal with precipitation not infiltrated into the soils. A later section on water storage describes that aspect of our investigations.)

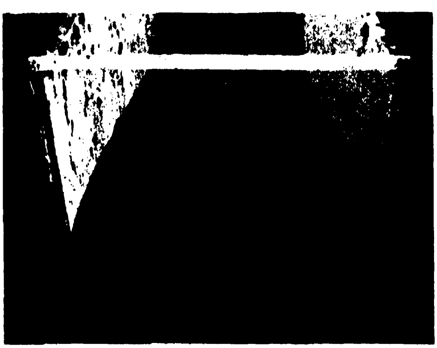
Table 30 summarizes data gathered on rainfall and runoff. Because of the high runoff associated with two high-intensity storms, we have also displayed data with the figures for those two storms omitted. Table 31.

Watershed BW-6C was planted flat on an area with contour bunds. Data indicate that watershed runoff under this management system was comparable to that under the ridge-and-furrow method. It was noted, however, that on the land with contour bunds, water stood above the bunds and eventually evaporated or infiltrated into that limited area. On the other hand, the ridge-and-furrow system distributed the intercepted water more uniformly over the entire area. When tillage began on the contour-bunded areas at the end of the monsoon, difficulties in workability were not unusual where water had ponded.

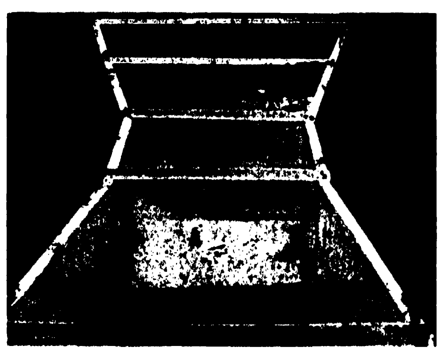
Soil Erosion

In addition to the amount of water lost by runoff, velocity and concentration of that runoff relates closely to soil loss by erosion. Table 30 reports the maximum discharge rates for these 13 catchments. Hydrographs of field-bunded BW4-B, with monsoon-fallowed black soil, showed more rapid discharge than occurred on BW-6B, which had contour bunds on an area that was also monsoon-fallowed. Areas cropped with ridges and furrows yielded hydrographs that were less steep, runoff continued over a longer period, and the peak discharges were substantially lower than those on the fallowed watersheds.

Table 30. Rainfall and runoff observations in the 1974 monsoon, with different management on black and red soils. Hyderabad 1974.								
Watershed		Soil	Treatment	Rain-fall mm	Storms causing runoff	Runoff		Maximum discharge M³/sec/ha
No.	Area ha					Amount mm	Percent	
BW-3A	4.3	Black	Ridge—0.4%	809	13	101	12.5	.016
BW-4A	5.1	Black	Ridge—0.4%	816	14	97	11.9	.009
RW-1	3.4	Red	Ridge—0.4%	826	21	204	24.7	.045
BW-1	3.5	Black	Ridge—0.6%	810	15	116	14.3	.025
BW-2	3.5	Black	Ridge—0.6%	806	11	101	12.5	.016
BW-3B	2.3	Black	Ridge—0.6%	807	14	105	13.0	.023
BW-5A	6.9	Black	Ridge—0.8%	824	16	133	16.1	.028
BW-5B	6.6	Black	Ridge—0.8%	809	16	146	18.0	.030
BW-6A	1.5	Black	Flat—mulch	822	12	141	17.1	.052
BW-6C	4.3	Black	Flat—contour	807	13	107	13.3	.042
BW-6B	4.2	Black	Fallow	814	15	241	29.6	.035
BW-4B	3.6	Black	Fallow	807	17	223	27.6	.113
RW-2	30+	Red	Grazed	786	25	183	23.3	.089



Muddy water runoff from monsoon-fallow watershed (BW4B) during a high intensity storm of 13mm on September 24.



A cropped watershed (BW3B) shows only slight runoff of clear water from the same storm.

Table 31. Rainfall and runoff observations in the 1974 monsoon, with different management on black and red soils — two high-intensity storms omitted. Hyderabad 1974.

Watershed		Soil	Treatment	Rain-fall mm	Storms causing runoff	Runoff	
No.	Area ha					Amount mm	Percent
BW-3A	4.3	Black	Ridge — 0.4%	655	11	20	3.6
BW-4A	5.1	Black	Ridge — 0.4%	661	12	17	2.6
RW-1	3.4	Red	Ridge — 0.4%	686	19	111	16.2
BW-1	3.5	Black	Ridge — 0.6%	655	13	30	4.6
BW-2	3.5	Black	Ridge — 0.6%	652	9	28	4.3
BW-3B	2.3	Black	Ridge — 0.6%	654	12	32	4.9
BW-5A	6.9	Black	Ridge — 0.8%	669	14	34	5.1
BW-5B	6.6	Black	Ridge — 0.8%	657	14	56	8.5
BW-6A	1.5	Black	Flat — mulch	667	10	64	9.6
BW-6C	4.3	Black	Flat — contour	656	11	28	4.3
BW-6B	4.2	Black	Fallow	663	13	183	27.6
BW-4B	3.6	Black	Fallow	655	15	138	21.1
RW-2	30+	Red	Grazed	629	23	93	14.8

Analysis of soil losses will be more complete in the coming years with installation of erosion monitoring equipment in the watersheds. We observed differences in soil losses associated with management systems in the black soils. Monsoon-fallowed black soil lost 7 t/ha of soil, about five times the loss from black soils farmed on the ridge-and-furrow system Within bunded watersheds that were flat-planted, we saw severe localized erosion where bunds broke through.

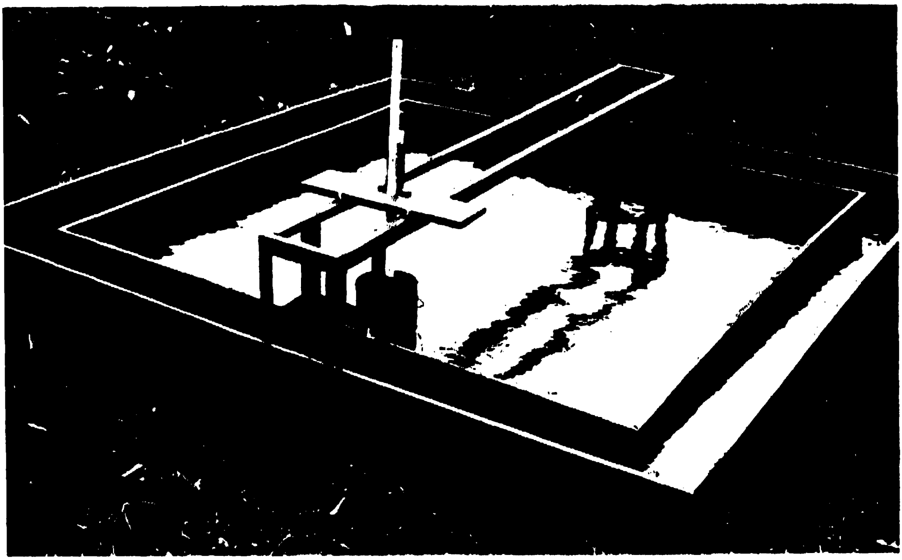
Infiltration Rates

Tropical-type storms often drop a relatively large amount in a short time. If that intensity exceeds the infiltration capacity of the soil for some time, runoff occurs.

We undertook our first research into the effect of the management system on infiltration rate on the black soils of the ICRISAT station. We had earlier observed, during high intensity storms, more standing water on monsoon-fallowed land than where the ridge-and-furrow system was in use. So our preliminary tests compared these two systems.

Eight large infiltrometers were used in the study. Rainfall was simulated with water applied from tankers — with care to minimize disturbance to the surface soil. We used point gauges to measure changes in water elevation over time.

In two sets of tests, the ridge-and-furrow system was found to support notably faster infiltration. This was true in initial stages and still after 48 hours or more. In one test the infiltration on the monsoon-fallowed land averaged 2.5 mm per hour; in the same test the rate on the ridge-and-furrow system averaged 6 mm per hour. In a second trial, monsoon-fallowed land took in water at a rate of 1 mm per hour, while the intake on the ridge-and-furrow land was 3 mm per hour.



A 2 x 2 m double ring infiltrometer in operation.

Soil Moisture

Black soil watersheds differ in depth of the soil profile. Those included in BW-1, BW-2, BW-3, and BW-4 are deep; BW-5A, BW-6A, and BW-6B are medium deep; BW-5B, BW-6C, and BW-8 are shallow. All are underlaid with a gravelly murram, which affected the depth to which the soil moisture probes could be installed.

On deep black soils, except for BW-2, the sampled profiles contained about 500 mm of soil moisture at the start of the season. BW-2 had not grown a crop in the post-monsoon season of 1973-74, and its beginning soil moisture supply was measured at about 600 mm. During the first two months of the monsoon, all the soils gradually increased their moisture content to about 800 mm. The August-September drought period in 1974 shows clearly in the figures that present the moisture samplings. After the monsoon, soil moisture decreased rapidly to about 600 mm and then held more or less stable through the rest of the dry season.

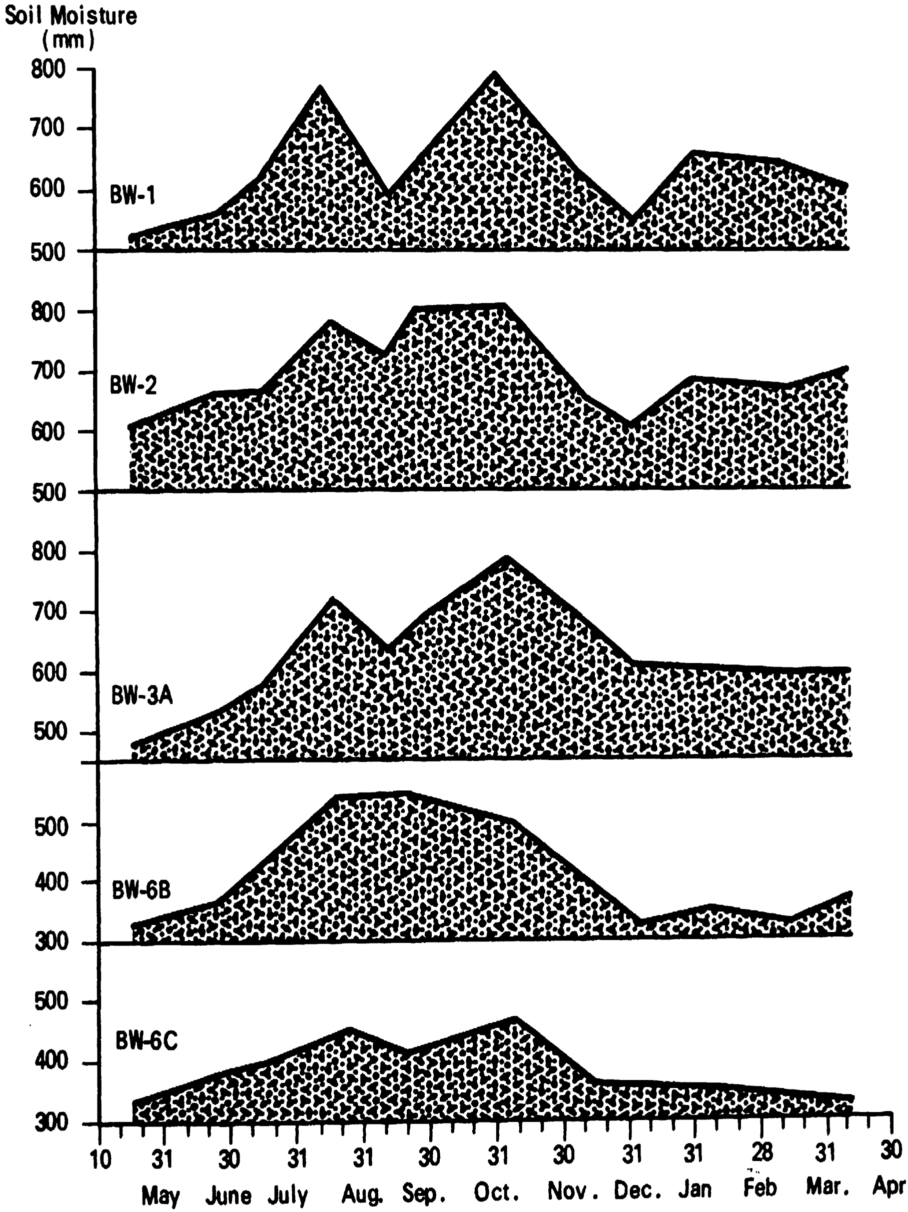
Among the deep black soils we found no significant differences in soil moisture traceable to different cropping systems. These soils added about 50 to 100 mm to their profiles during the course of the year. Some of this may have been due to the timing of dry season land preparation. Preparations for the 1974 crop came late in the dry season and not long before the start of the monsoon. In 1975, however, the ground was worked early, which created a soil mulch. The mulch might have reduced evaporation from the deep cracks that commonly occur in these black soils in the dry season.

On the basis of these observations, we find no advantage in monsoon-fallowing as a means of soil moisture conservation.

Runoff Collection and Irrigation

If all humid season rainfall in the semi-arid tropics could be held for use by plants, farm production would be higher and more stable year-to-year. From its inception the ICRISAT Farming

Measurements of soil moisture on five black soil watersheds; the depth of the sampled profile is 180 cm on BW 1 - 3A and 120 cm on BW 6B and 6 C.



Systems Research program has emphasized more efficient management of rainfall moisture. A principal line of study involves small-capacity storage structures designed to catch runoff and hold it for use on the catchment area where it fell.

Storage structures were available on six watersheds for 1974-75. Four were on black soils and two on red soils. All filled early in the monsoon season; some water was used from the tanks to offset the August-September drought. Rainfall in the late-monsoon period, in addition to the remainder of that caught and held earlier, meant that the tanks and soils went into the dry season well-supplied with water.

One concern in this system relates to losses of stored water due to evaporation and seepage. Water lost in these ways, of course, cannot support improved plant performance. Early in the dry season, evaporation losses were about the same for all tanks, falling in a range of 3 to 5 mm per day. Seepage losses showed more range — 2.6 to 18.3 mm per day — even for storage units that were close. For example, the tanks in BW-5A and BW-6C are less than 500 m apart, but the seepage losses in the latter were seven times greater than in the former.

Supplemental Irrigation

Stored water in RW-1, a red soil watershed, was used in August to counteract an extended dry period. Sorghum, millets, sunflower, and maize received lifesaving applications from stored water that had fallen earlier on that watershed. Table 32 reports the results of the 5-cm application.

Sorghum and maize showed the greatest yield responses to the additional water. These irrigations came at critical periods in the plant development. Sorghum was in the grain-formation stage, and maize was in immediate pre-tassel stage. Pearl millet and sunflower showed increases but not of the same magnitude.

When these four crops were harvested from the red soil watershed, we calculated the economic value of the increase due to water caught and used on the watershed. Using grain prices current at the time of harvest, we found these gross values per hectare attributable to the irrigation: Maize, Rs. 3,120; sorghum, Rs. 2,780; pearl millet, Rs. 1,085; and sunflower, Rs. 650.

The irrigation was applied in the ridge-and-furrow planting system. Some was applied to

Table 32. Effect of 5-cm irrigation applied in August drought on red soils — water taken from runoff stored on the watershed area. Hyderabad 1974.

Crops	Grain Yields — q/ha		Percent
	No irrigation	5-cm irrigation	increase
Sorghum	18.8	38.8	106
Sorghum	18.8	38.4	105
Pearl Millet	20.5	24.0	17
Pearl Millet	20.4	32.4	59
Maize	29.6	57.5	95
Maize	25.8	42.4	65
Sunflower	9.3	11.8	27
Sunflower	9.0	12.0	32

Maize on left received a 5 cm "life saving" irrigation; maize on right received none. Maize on the left (full basket) yielded 57.6 q/ha; maize on the right produced a yield of 29.6 q/ha.

every furrow in one series and to alternate furrows in another. We found no difference in the two methods of distribution.

Water collected and stored on four black soil watersheds was used on maize and sunflower during the August-September drought. Six plots of maize were irrigated, and water was added to four plots of sunflower. Grain yield responses were less spectacular than on the lighter red soils. One maize plot on medium deep black soil yielded 47 percent more than rainfed plots, but the average increase was 4 percent for five irrigated maize plots on deeper soils. Four irrigated sunflower plots averaged 6 percent more grain than plots that did not receive supplemental water.

Our experience to date with supplemental irrigation on black soils during the monsoon causes us to question this use of stored water. Except for an extreme drought — worse than the 1974 dry period, the collected water will probably return more crop increase on black soils if used in the subsequent dry season.

ECONOMICS

- Crop Improvement Support
- Farming Systems Support
- Production Economics
- Marketing Economics

Economics

Economic research at ICRISAT falls into two broad categories: (1) projects directly supporting programs in Crop Improvement and Farming Systems, and (2) studies designed to aid decision makers in the field — such as farmers, extension workers, and policy makers — or to define ICRISAT's research policies more precisely.

ICRISAT Goals

The general goal of our research in economics is "to identify socio-economic and other constraints to agricultural development in the semi-arid tropics and to evaluate alternative means of alleviating them via technological and institutional changes." More specific activities include:

1. Continuing research to delineate, differentiate, and describe the semi-arid tropics;
2. Economic and social analyses of present conditions in agricultural production, marketing, and human nutrition in the semi-arid tropics;
3. Analyses of proposed technological improvement and institutional changes and evaluation of their economic feasibility and social viability;
4. Broadening of information and data bases for continuously adjusting and improving research strategies and for allocating research resources so as to remove the most critical constraints to agricultural development. This should help maximize the expected payoffs from research undertaken at ICRISAT.

We pursue these goals within the crop breeding program by analyzing the impacts of choosing certain characteristics for which to breed. We monitor experiments at the research farm, as well as survey conditions in farmers' fields, to feed back relevant findings to the Farming Systems program. A number of independent projects focus on identifying and overcoming various constraints to agricultural production and marketing in the semi-arid tropics.

Crop Improvement Support

Two studies will help to define and refine breeding objectives and research strategies for the Crop Improvement program. One deals with the nutrient status of the population of the semi-arid tropics, and the other relates to consumer preferences for quality characteristics in grain.

The first of the studies provides a guide for allocating research resources in breeding by explicitly considering nutritional needs and the ease with which nutritional attributes can be bred into new cultivars. The second may give breeders a better understanding of which quality characteristics are important to consumers and, hence, should be maintained or improved in the breeding program.

For many years it has been widely believed that a shortage of protein is the major nutritional problem facing the world in general and the developing countries in particular. The almost unquestioned belief in the primary importance of the so-called protein gap led to many research programs and nutritional schemes whose objectives were to increase protein quantity and quality in the human diets.

However, during the past few years, closer analysis suggests that the importance of protein deficiency has been overemphasized, while the problem of insufficient calories has been underemphasized. We have compared secondary data recently available from India, West Africa, East Africa, Brazil, and Thailand with the energy and protein requirements as recommended in recent publications of Food and Agriculture Organization World Health Organization and other bodies. The results of our study indicate that for the majority of people living in the semi-arid tropics, calorie deficiencies predominate; protein and lysine seem to be available in adequate amounts, even to low income groups. When protein is adequate but calories are deficient, the protein is utilized to provide energy;

thus some apparent protein deficiencies probably occur indirectly from calorie deficiency

We believe that improvement in the quality and quantity of protein in the existing diets of vulnerable groups will not achieve as much nutritional improvement as will an increase in the amount of their intake — a greater quantity of their typical foods will supply much needed calories and also augment the protein aspect Our findings suggest that ICRISAT's breeding strategy should focus on yield enhancement, together with disease and other environmental resistances to reduce the variability of yields

We question whether improved protein and lysine content, while desirable in themselves should rate a high priority Instead, we suggest that the carbohydrate content of grain should receive more attention to reduce deficiencies in calories throughout the semi arid tropics Although the major component of both cereal and pulse grains is carbohydrate only a portion is digestible and the remainder consists of indigestible cellulose and other cell wall constituents

There is some evidence that the amount of starch in sorghum grain varies from cultivar to cultivar But breeding programs generally have not given much attention to the starch content In fact, the starch content of many commonly cultivated food grains seems to be unknown We think screening for digestible carbohydrates (starch and free sugars) and breeding to increase their content could be an important part of the breeding program at ICRISAT More basic research on this is required before a decision can be made, however

In developing cultivars with improved agronomic and nutritional characteristics, other traits related to consumer preferences and the marketability of crops should not be ignored A superior, high-yielding cultivar may not be adopted widely if it lacks quality characteristics important to consumers and traders

We don't know the relative importance of quality traits that are readily evident to consumers We are trying to provide quantitative measures of consumer preferences for relevant characteristics in sorghum, pearl millet, chickpea, and pigeonpea Once suitable laboratory techniques for measuring evident quality characteristics are developed, we will determine consumer preferences for those various traits

Indicators of quality characteristics that we are considering include 100 seed weight, volume of dry seed, water uptake after 24 hours of swelling, swelling after 24 hours of soaking, and color mix Some of these characteristics are related to other less evident but relevant characteristics such as cooking time, swelling after cooking keeping quality of cooked cereals, and dal yield from pulses

We are measuring preferences for these characteristics in three ways (1) by collecting market samples and correlating prices and measured qualities, (2) by presenting samples of defined qualities to traders and asking them to rank samples, and (3) by asking consumers to test defined samples and to rank the samples according to preference We expect to correlate prices and measure qualities of market samples with preferences as ranked by traders and consumers If we find a significant correlation, analysis of market samples would be an efficient way to evaluate consumer preferences

Farming Systems Support

We carry out continuing economic analyses of the experiments conducted in the Farming Systems program An economics field assistant monitors all activities, collecting data on time spent in various operations and the inputs applied in experimental treatments We calculate the total net income generated from different treatments, using data on inputs, yields, and market prices for the various crops produced

These analyses let us compare the economic advantages of systems with different crops, treatments, and amounts or kinds of inputs We have analyzed experiments conducted in 1973 on intercropping, ratooning, relay cropping, method of planting fertilization, and irrigation We seek to identify the most profitable production systems and to guide future experiments The details of these experiments were described in the annual report for 1973 74

Estimates of benefits-costs of the first year's activities on the black soil watersheds (BW 1 to BW 5) were compiled in collaboration with the staff of Farming Systems and Farm Development and Operations. Although we don't consider the results as accurate estimates of what it would cost to develop such systems under actual farming conditions — nor of their expected benefits — the analysis helps to pinpoint areas of economic strength and weakness.

Other studies of technical aspects of water harvesting and irrigation are providing information for further development and testing of the experimental watersheds. Our analysis of the comparative costs of pipe-lift and gravity-flow irrigation systems showed that gravity-flow systems can be about 30 percent cheaper. An unlined gravity-flow system could sustain evaporation and seepage losses ranging from 64 to 82 percent before its economic cost of delivering water would equal that for the pipe-lift system. Research is now proceeding in Farming Systems to determine precisely the economics of both.

The capacity and location of a storage tank for gravity irrigation are important considerations in watershed development. We developed a mathematical model for determining the optimal size and location for a dug tank with gravity irrigation. Solution of the model depends on the response of crops to water, the cost of water per effective unit, and the amount and efficiency of rainfall available.

We have started work on a larger model for estimating the returns from water harvesting and supplementary irrigation. This model will permit us to simulate impacts of actual rainfall data and other variables on the performance of the system. The model can be used to identify the various regions of the semi-arid tropics where water harvesting and supplementary irrigation have the greatest potential. We are also undertaking a study of traditional tank irrigation systems in southern India to determine their economic history and costs and benefits.

Production Economics

We are cooperating with other ICRISAT researchers in a series of village level studies to identify the economic, institutional, and biological constraints of traditional farming systems in the semi-arid tropic parts of India. These studies focus on such issues as the economic and environmental causes of present cultivation practices; seasonal pattern of resource availabilities, bottlenecks in resource use, and utilization pattern of resources (labor, power, water, etc.); impact of risk and uncertainty on decision making by farmers; problems of group action; consumption and nutritional status of different population groups; problems of product dispersal, etc.

Investigators are interviewing in sample households in three districts with varying rainfall and soil conditions. Two villages have been selected for detailed study in each of the three districts, Sholapur and Akola (in Maharashtra state) and Mahbubnagar (in Andhra Pradesh). Interviewers use 12 schedules to collect data on the social and economic characteristics of household members, production and marketing practices, labor use, investment and savings behavior, village institutions, management of watersheds, and more. Data collection for these studies began in May 1975 and will continue for one to two years.

Associated with the village level studies is a project to investigate risk aversion as a factor affecting the rate of adoption of modern farming methods. Modern techniques generally increase average returns over years and reduce the risk of crop failure; but most require larger investments in money, labor, or other owned inputs. Modern techniques thus may increase financial risk, the possible inability to pay for inputs out of crop returns in bad years.

We will measure the changes in yield and financial risk associated with various modern techniques determining the overall risk involved. However, an increase in riskiness of a modern method would be expected to reduce the rate of adoption only if farmers were risk-averse. Thus, we need to assess farmers' attitudes toward risk, studying their present behavior in relation to existing practices that differ in risk.

Marketing Economics

A major set of constraints to agricultural development in the countries of the semi-arid tropics is thought to be the marketing chain from the producer to the consumer via traders and perhaps processors. Various characteristics of the marketing system, as well as the low price elasticities for sorghum, millet, and the pulses to some extent, may affect farmers' interest in growing crops for market

We are studying the market system in Mahbubnagar district We will look into the effect of density and location of market facilities on marketing costs for farmers, we will identify socio-economic conditions that reduce use of the market channels and analyze different operational characteristics of the rural marketing system

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