



# India and the International Crops Research Institute for the Semi-Arid Tropics

A Study of Their Collaboration in Agricultural Research

Ishwar Chandra Mahapatra  
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Shriniwas Dattatraya Bokil



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**India and the International Crops Research Institute  
for the Semi-Arid Tropics**

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Consultative Group on International Agricultural Research

**CGIAR**

Study Paper Number 18

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Institute for the Semi-Arid Tropics**

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At its annual meeting in November 1983 the Consultative Group on International Agricultural Research (CGIAR) commissioned a wide-ranging impact study of the results of the activities of the international agricultural research organizations under its sponsorship. An Advisory Committee was appointed to oversee the study and to present the principal findings at the annual meetings of the CGIAR in October 1985. The impact study director was given responsibility for preparing the main report and commissioning a series of papers on particular research issues and on the work of the centers in selected countries. This paper is one of that series.

The judgments expressed herein are those of the author(s). They do not necessarily reflect the views of the World Bank, of affiliated organizations, including the CGIAR Secretariat, of the international agricultural research centers supported by the CGIAR, of the donors to the CGIAR, or of any individual acting on their behalf. Staff of many national and international organizations provided valued information, but neither they nor their institutions are responsible for the views expressed in this paper. Neither are the views necessarily consistent with those expressed in the main and summary reports, and they should not be attributed to the Advisory Committee or the study director.

This paper has been prepared and published informally in order to share the information with the least possible delay.

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## SUMMARY

This study focuses on the contribution of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) to increasing the agricultural production and research capacity of the semi-arid tropics of India. It differs from the other country studies conducted under the auspices of the impact study of the CGIAR in that the impact of only one center, ICRISAT, in only one ecology of India, the semi-arid tropics, is considered. The study was deliberately limited by Jock Anderson, director of the impact study, because of the wealth of material on other CGIAR activities in India, especially with respect to modern wheat and rice varieties.

There are more than 20 research centers in India studying dryland agriculture, and approximately 1,300 researchers work on the all-India projects for sorghum, millets, pulses and oilseeds. Complementing these efforts directed at the semi-arid tropical areas are the activities of ICRISAT, which can undertake more strategic research than most domestic institutes.

National researchers have released many varieties and hybrids of sorghum, pearl millet, chickpea, pigeonpea and groundnut, while ICRISAT-developed varieties are just beginning to emerge from the national test and verification system -- an understandable situation, given the relatively recent involvement of ICRISAT in the area.

ICRISAT has a formal agreement with the government of India and also works with many Indian scientists on an informal basis. Collaboration between

ICRISAT and the national system is characterized by the free flow of genetic materials and information and joint participation in planning and designing research investigations and developing and testing new research methods.

The crop germplasm obtained from India by ICRISAT has been supplemented with germplasm from other countries, and the improved seeds have been widely distributed in India. In 1983 alone, more than 11,000 samples of seeds were distributed on request to Indian scientists. Some 215 Indian researchers have participated in various training programs at the center.

According to a survey of Indian scientists conducted as part of this evaluation, the linkage between ICRISAT and the national research system is very good. One-half of the respondents rated the quality of services from ICRISAT as "very good" and 40 percent rated them as "good."

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Many institutions, organizations and departments that work with the crops within ICRISAT's mandate (sorghum, pearl millet, chickpea, pigeonpea and groundnut) and with ICRISAT technologies (for example, farming systems that include socioeconomic studies) were contacted in the course of this study. We met with administrators, research and extension leaders, principal scientists and professionals from more than 20 institutions -- in Andhra Pradesh, Bihar, Karnataka, Madhya Pradesh, Maharashtra, Orissa, Rajasthan and Tamil Nadu -- and asked them to complete our questionnaire. We are grateful to all the institutions and scientists who responded. In view of the shortage of space and to avoid repetition, we respectfully acknowledge their help without mentioning their names here. We also collected a large number of publications and documents from several sources, to whom we express our gratitude.

We are also grateful to CGIAR, especially Jock R. Anderson and Carl E. Pray, for giving us the opportunity to work on the impact study and for providing us with guidelines from time to time.

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ACRONYMS

CGIAR-supported centers

|         |  |
|---------|--|
| CIAT    | Centro Internacional de Agricultura Tropical                     |
| CIMMYT  | Centro Internacional de Mejoramiento de Maiz y Trigo             |
| CIP     | Centro Internacional de la Papa                                  |
| IBPGR   | International Board for Plant Genetic Resources                  |
| ICARDA  | International Center for Agricultural Research in the Dry Areas  |
| ICRISAT | International Crops Research Institute for the Semi-Arid Tropics |
| IFPRI   | International Food Policy Research Institute                     |
| IITA    | International Institute of Tropical Agriculture                  |
| ILCA    | International Livestock Center for Africa                        |
| ILRAD   | International Laboratory for Research on Animal Diseases         |
| IRRI    | International Rice Research Institute                            |
| ISNAR   | International Service for National Agricultural Research         |
| WARDA   | West Africa Rice Development Association                         |

# 1 India's Agriculture and Agricultural Research System

## 1.1 Introduction

In India, the "green revolution" was primarily due to applied and adaptive research backed by a strong extension program. Recognizing the importance of dryland agriculture, national research efforts directed at it have been vigorously pursued through various schemes for decades. Currently 15 research institutes, 23 agricultural universities and a number of all India coordinated research and transfer of technology projects of the Indian Council of Agricultural Research (ICAR) are directly or indirectly involved in research and extension on sorghum, pearl millet, chickpea, pigeonpea, groundnut, farming systems and socio-economic studies in rainfed agriculture (dryland agriculture in semi-arid and arid tropics).

The ICAR is responsible on a national basis for coordinating research, education and extension education in agriculture, animal husbandry and fisheries sciences. It performs these functions through a national grid of cooperative research in which central institutes and agricultural universities in different states participate as equal partners. It employs approximately 6,000 scientists, while the agricultural universities employ another 8,000 in teaching, research and extension.

Thus, India has strong nationally supported research institutions that can link with international efforts such as those of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). The combination has the potential to be highly productive. This monograph reports on an examination of the contributions that have been made by ICRISAT and the

national research efforts to improve the productivity of agriculture in the semi-arid tropics (SAT) of India. The emphasis is on the contributions made by cooperative research or by research that had inputs from both ICRISAT and national researchers.

## 1.2 India's agricultural performance

Selected economic indicators reflecting the performance of India's economy and its agriculture are given in Table 1.1. The index number of agricultural production (all commodities) has increased from 58.5 in 1951 to 135.2 in 1981, taking the triennium ending 1970 as 100. There has been a gradual increase in agricultural production from 1951 onwards except for bad monsoon years. This increase has been due, among other factors, to the increase in irrigated area. The increase in agricultural production has led to a corresponding increase in contribution of agriculture to national income from Rs. 98 billion to Rs. 189 billion. However, the growth in population has been rather rapid resulting in slow growth of per capita income. Thus, while agriculture has contributed substantially to the growth of national income, the increase in per capita income has not been impressive because of growth in population.

Agricultural Growth. Between the years 1960-61 and 1980-81, agricultural production (Table 1.2) increased at the rate of 2.29 percent per annum which was slightly higher than the rate of population growth (2.26%). During the same period the production of foodgrains increased at the rate of 2.41 percent and cereals at 2.80 percent. Among the ICRISAT mandate crops, sorghum yield per hectare registered a growth rate of 1.8 percent and

Table 1.1 Selected Economic Indicators for India

| Item/Unit <sup>a</sup>                                  | 1951   | 1961   | 1971   | 1976   | 1977   | 1978   | 1979   | 1980   | 1981   |
|---|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| Population (million)                                    | 361    | 439    | 547    | 609    | 622    | 634    | 647    | 659    | 684    |
| National income (Rs. crores)                            | 16,731 | 24,250 | 34,235 | 40,064 | 40,606 | 44,090 | 46,306 | 43,822 | 47,211 |
| National income from agriculture (Rs. crores)           | 9,859  | 13,143 | 16,354 | 18,066 | 16,998 | 19,045 | 19,310 | 16,723 | 18,902 |
| Per capita income (Rs.)                                 | 466    | 559    | 633    | 661    | 659    | 701    | 715    | 661    | 696    |
| Money supply with public (Rs. crores)                   | 2,016  | 2,869  | 7,321  | 13,144 | 15,609 | 18,383 | 21,819 | 24,272 | 23,210 |
| Plan investment (Rs. crores)                            | -      | 1,117  | 2,524  | 6,417  | 8,082  | 9,226  | 11,444 | 12,601 | 15,058 |
| Total plan investment, agriculture and allied sector    | -      | 71     | 374    | 716    | 970    | 1,264  | 1,765  | 1,815  | 2,432  |
| Total cropped area (million hectares)                   | 132    | 153    | 166    | 171    | 167    | 172    | 175    | 169    | 170    |
| Net irrigated area (million hectares)                   | 20.9   | 24.7   | 31.1   | 34.5   | 35.1   | 36.6   | 38.0   | 38.3   | 41.1   |
| Gross irrigated area (million hectares)                 | 22.6   | 28.0   | 38.2   | 43.2   | 43.5   | 46.0   | 48.2   | 48.9   | 51.1   |
| Index number of area under crops (1968-70=100)          |        |        |        |        |        |        |        |        |        |
| (i) Cereals   | 78     | 92     | 102    | 104    | 102    | 104    | 106    | 103    | 103    |
| (ii) Foodgrains   | 79     | 95     | 102    | 105    | 102    | 104    | 106    | 103    | 103    |
| (iii) Non-foodgrains                                    | 74     | 93     | 104    | 108    | 107    | 112    | 116    | 109    | 112    |
| Index number of agricultural production (1968-70=100)   |        |        |        |        |        |        |        |        |        |
| (i) Cereals   | 54     | 83     | 114    | 129    | 118    | 137    | 144    | 120    | 143    |
| (ii) Foodgrains   | 57     | 86     | 113    | 127    | 116    | 134    | 139    | 115    | 138    |
| (iii) Non-foodgrains                                    | 62     | 88     | 109    | 120    | 118    | 131    | 135    | 122    | 130    |
| (iv) All commodities                                    | 59     | 87     | 112    | 125    | 116    | 133    | 138    | 117    | 135    |
| Index number of agricultural productivity (1968-70=100) |        |        |        |        |        |        |        |        |        |
| (i) Cereals   | 69     | 91     | 111    | 119    | 111    | 125    | 129    | 110    | 130    |
| (ii) Foodgrains   | 72     | 93     | 110    | 117    | 109    | 122    | 128    | 106    | 127    |
| (iii) Non-foodgrains                                    | 87     | 97     | 105    | 112    | 109    | 115    | 115    | 111    | 116    |
| (iv) All commodities                                    | 76     | 94     | 108    | 116    | 109    | 120    | 122    | 108    | 124    |

<sup>a</sup> Financial data based on 1970-71 prices, crore = 10 million.

Source: Directorate of Economics and Statistics, Ministry of Agriculture, Government of India.

production increased at the rate of 0.8 percent despite the decline in area. Pearl millet yield per hectare increased at a rate of 1.8 percent and production at 1.7 percent. Among the pulse crops, yield per hectare of chickpea increased at a rate of 0.3 percent though the total production showed a declining trend because of decline in area. This decline is mainly due to competition from wheat cultivation, which became more profitable in recent years. Pigeonpea, had an annual growth rate of yield per hectare of 0.4 percent and of production 0.8 percent.

Cropping Intensity. The growth in agricultural production has been achieved to a considerable extent by increases in gross cropped area, achieved largely through increases in cropping intensity. The net area sown (i.e. physical area) increased from about 120 million hectares in 1950-51 to about 143 million hectares in 1980-81 while the gross cropped area (area counted each time a crop is harvested from it) increased from 132 million to 175 million hectares, an increase of nearly 33 percent. Thus cropping intensity increased from 110 percent to 122 percent.

Food Production. The most important benefit arising from the progress of agriculture is the improvement in the food situation. The production of foodgrains increased from 50 million tons in 1951-52 to 150 million tons in 1983-84. Among the foodgrains the annual rate of growth of cereal production was higher than the pulses. The annual rate of growth in production was highest in wheat (7.2%), followed by rice (1.9%), finger millet (1.8%), maize (1.75%), pearl millet (1.7%), sorghum (0.8%), pigeonpea (0.8%), and chickpea (-1.2%). The overall annual rate of growth in production of pulses has been negative (-0.5%) primarily due to decline in the area under

Table 1.2 Compound Growth Rates of Area Under Crops, Agricultural Production and Yield During 1960-61 to 1980-81 and 1967-68 to 1980-81, India

| Crop/Group of Crops  | 1960-61 to 1980-81 |            |       | 1967-68 to 1980-81 |            |       |
|----------------------|--------------------|------------|-------|--------------------|------------|-------|
|                      | Area               | Production | Yield | Area               | Production | Yield |
| Rice                 | 0.72               | 1.92       | 1.19  | 0.73               | 2.20       | 1.4   |
| Sorghum              | -0.95              | 0.81       | 1.77  | -1.18              | 2.06       | 3.2   |
| Pearl millet         | -0.13              | 1.70       | 1.82  | -1.16              | -0.34      | 0.7   |
| Maize                | 1.45               | 1.75       | 0.30  | *                  | -0.05      | -0.0  |
| Finger millet        | *                  | 1.82       | 1.84  | 0.69               | 3.43       | 2.7   |
| Wheat                | 3.26               | 7.20       | 3.81  | 2.92               | 5.65       | 2.6   |
| Barley               | -2.41              | -0.97      | 1.44  | -3.86              | -2.76      | 1.0   |
| All cereals          | 0.65               | 2.80       | 1.73  | 0.36               | 2.69       | 1.8   |
| Chickpea             | -1.53              | -1.24      | 0.27  | -0.49              | -0.83      | -0.3  |
| Pigeonpea            | 0.36               | 0.78       | 0.41  | 0.34               | 0.65       | 0.3   |
| All pulses           | -0.35              | -0.55      | -0.04 | 0.44               | -0.28      | -0.5  |
| All foodgrains       | 0.44               | 2.41       | 1.54  | 0.35               | 2.39       | 1.5   |
| Groundnut            | -0.01              | 0.62       | 0.63  | -0.26              | 0.65       | 0.8   |
| Sesamum              | -0.19              | 0.46       | 0.66  | -0.36              | -0.36      | 0.0   |
| Rapeseed and mustard | 1.19               | 2.38       | 1.17  | 1.31               | 1.43       | 0.1   |
| All oilseeds         | 0.18               | 1.23       | 0.74  | 0.27               | 1.04       | 0.7   |
| Fibers               | -0.33              | 1.21       | 1.50  | 0.23               | 2.61       | 2.1   |
| Non-foodgrains       | 0.67               | 2.05       | 1.04  | 0.97               | 2.34       | 1.1   |
| All crops            | 0.50               | 2.29       | 1.39  | 0.52               | 2.37       | 1.4   |

\* = Negligible.

Source: Directorate of Economics and Statistics, Ministry of Agriculture, Government of India.

chickpea. The moment any irrigation potential is created in an area, farmers grow cereals such as wheat and rice in preference to pulses. It is necessary, therefore, to emphasize that greater attention needs to be given to this rainfed group of crops to achieve quantitative and qualitative improvement.

### 1.3 Agriculture in the semi-arid tropics of India

Nearly 80 percent of the geographical area of India falls in the semi-arid tropics where monthly rainfall exceeds potential evapo-transpiration for 2 to 7 months and mean monthly temperature is above 18°C. Within this agroclimatic zone, the areas with 2 to 4.5 humid months are called the dry semi-arid tropics and those with 4.5 to 7 humid months a year are called wet-dry semi-arid tropics. Most of the Indian SAT falls in the category of dry semi-arid tropics. Nearly 550 million people of India live in the semi-arid tropics, cultivating more than 115 million hectares of land.

The mean annual rainfall of SAT India varies from 500 mm to 1,400 mm most of which is received in a period of 3 to 4 months (June to September) in a few rainy days. The growing period varies from about 8 weeks to more than 40 weeks depending upon the rainfall, its distribution and the potential evapotranspiration. There is wide variation in the amount of rainfall from year to year. The coefficient of variation increases with decreasing rainfall. The aberrations in rainfall include delay in the onset of the monsoon, long dry spells and early withdrawals of the monsoon.

The dominant soils in the semi-arid tropics are black (vertisols and vertic), red and laterite (alfisols, oxisols and ultisols) and alluvial

(entisols and inceptisols). Some of the desert soils (aridisols) also fall in the semi-arid tropics.

#### 1.4 SAT crop production

Next to rice and wheat, sorghum is the most extensively grown cereal crop of India. Nearly 95 percent of the area of sorghum is grown without irrigation. Even though the area of the crop decreased from 18 million hectares in 1973-74 to 16 million hectares in 1982-83, its production increased from 9.3 to 11.2 million tons due to increases in yield per hectare. Sorghum is grown both in the rainy season and in the post-rainy season. The average yield of rainy season sorghum increased from 540 kg/ha to 770 kg/ha and that of post-rainy season crop from 480 kg/ha to 540 kg/ha.

In Maharashtra, nearly two-thirds of the rainy season sorghum is under high-yielding hybrids or varieties, which are also important in Karnataka. Currently, the most popular hybrid is CSH-9, developed by the All India Coordinated Sorghum Improvement Programme. In most of the other sorghum growing areas, sorghum straw is the main source of animal feed and the farmers are hesitant to shift to dwarf cultivars. The major biotic factors responsible for reducing grain yield are grain mold, downy mildew, anthracnose, rust, charcoal rot, striga, stalk rot, stem borer, shoot fly, midge and head bug.

The area of pearl millet in India decreased to 10.9 million hectares in 1982-83 from 13.9 million hectares in 1973-74. About 40 percent of the crop is grown in arid areas where its straw is an important source of animal

feed. The farmers would probably continue to grow pearl millet for fodder even if the grain yield is low. The average grain production of pearl millet increased from 3.86 million tons for the quinquennium ending 1964-65 to 5.17 million tons for the quinquennium ending 1979-80; average yield during the same period increased from 339 kg/ha to 467 kg/ha. The highest production of pearl millet was in 1970-71 when it reached 8.03 million tons and the yield was 622 kg/ha. Apart from good climatic conditions, the availability of well-adapted hybrids resulted in high yields. Later these hybrids succumbed to diseases leading to a fall in production. The major yield reducers are downy mildew, ergot, smut, rust, drought, high temperature and crusting of soils. More than 90 percent of the area under pearl millet does not have irrigation facilities.

Chickpea is the most important pulse crop of India accounting for about 30 percent of the total area and 40 percent of total production of pulses. It is grown on 7.5 million hectares in the post-rainy season with production of slightly less than 5 million tons. Its share in area and production of pulses has been declining over the years and its average yield has remained stagnant at about 700 kg/ha. Like most other pulses, it is a high risk crop sensitive to adverse soil and climatic conditions. Year to year fluctuation of area and production is high. In years when the monsoon rains withdraw early, sown area declines because of the lack of moisture. In a wet year the crop may be entirely destroyed due to diseases like Ascochyta blight and Botrytis. Chickpea is highly sensitive to water logging and salinity. Nearly 85 percent of the nation's chickpea is grown in the four states of Madhya Pradesh, Uttar Pradesh, Rajasthan and Haryana in the northern part of the country. With the spread of irrigation, the area of chickpea has

been declining rapidly particularly in Uttar Pradesh and Punjab because of the diversion of the area to wheat which is a safer crop and is less sensitive to a high water table, excess moisture and salinity than is chickpea. Only 9 percent of the chickpea is grown in peninsular India in the states of Maharashtra, Karnataka and Andhra Pradesh. The yield of chickpea in these states is less than 350 kg/ha probably because of the shorter growing season. Heliothis is the major pest of the crop though in some years cutworm may prove disastrous. Blight, Botrytis and wilt complex are the major diseases.

Pigeonpea occupies more area than any other pulse crop in the rainy season in India. Since 1960-61 its area has been around 2.6 million hectares. During the same period production was about 1.7 million tons. Since 1980-81 there has been a trend of increasing yield and production. Maharashtra, Madhya Pradesh, Uttar Pradesh and Karnataka have about 70 percent of the country's pigeonpea area, accounting for nearly 75 percent of production. The other pigeonpea growing states are Andhra Pradesh, Tamil Nadu, Gujarat, Bihar, Orissa and West Bengal. Pigeonpea seems to be replacing maize in the Punjab and Haryana and unirrigated cotton in some districts of Gujarat. The incentive for this increase is the high price. The yield of pigeonpea varies a great deal from state to state. In Uttar Pradesh it is more than one ton, in Maharashtra, Madhya Pradesh and Karnataka it is about 600 kg/ha, and in Andhra Pradesh the average yield has remained about 400 kg/ha. The major yield reducers are wilt, sterility mosaic, blight, Heliothis and pod fly.

Groundnut. Although India ranks first in the world in the groundnut area (7.1 million hectares) and production (5.83 million tons), it ranks only

tenth in productivity. The area under groundnut has been nearly constant over the past decade, while the production has increased by 15 percent and productivity by 11 percent to 840 kg/ha. The increase in the area under rabi (post-rainy season) and summer groundnut is taking place in the states of Orissa, Gujarat, Maharashtra, Tamil Nadu, Karnataka and Andhra Pradesh.

The causes of low groundnut yield in the country are lack of and untimely supply of quality seed, low seeding rate of improved varieties, suboptimal plant population, (low seed rate, non-selection of good seeds and use of untreated seeds), improper seed bed preparation, lack of weed control, inadequate manuring and fertilizer application, soil deficiencies of calcium, sulphur and zinc, non-use or application of inefficient strains of Rhizobium and inefficient and inadequate plant protection measures against serious diseases and pests (leaf spot, rust, pod rot, bud necrosis, aflatoxin, spodoptera and leaf miner, etc.).

In all, about 60 groundnut varieties have been released by different states for general cultivation. Since the All India Coordinated Research Project on Oilseeds came into operation in 1968, as many as 29 improved groundnut varieties have been released. But seed multiplication, seed dormancy and seed storage during rainy season and the timely distribution of seeds to the farmers still continue to pose serious problems in the country.

## 2 The National SAT Research System and Its Impact

### 2.1 National policies and support services

The problems of dryland agriculture are now receiving greater attention than ever before. Although doubts continue to be expressed about the availability and effectiveness of new technologies for increasing crop yields under conditions of dryland agriculture, the concerted research work of ICAR and ICRISAT has provided the basis for cautious optimism that, given adequate inputs and extension support, it is possible to sustain at least a moderate increase in yield of coarse grains, pulses, oilseeds and cotton even for this type of agriculture.

The major production-oriented initiatives taken by the Ministry of Agriculture and the State Departments of Agriculture are related to inputs like seeds, fertilizers, plant protection chemicals and agricultural implements and machinery. Incentives to the farmers were increased through upward revision of agricultural commodity prices and subsidies on fertilizers and other inputs. Specially designed schemes to benefit the small and marginal farmers in increasing agricultural production are being mounted throughout the country.

Sustained efforts have been made to increase the efficiency of agricultural extension to play its pivotal role in agricultural production. The system is designed to provide a direct and effective transfer of available technical recommendations through close linkage between research, extension service and farmer, ensuring at the same time effective feedback of field

problems so that research becomes more practical and field oriented. The role of the training and visit (T & V) system of extension is particularly perceptible in the introduction of new crops in non-traditional areas, introduction of new crop rotations and increasing the intensity of cropping. The large increase in the area under soybean in Madhya Pradesh, the extension of area under summer groundnut in Gujarat and Maharashtra and increase in the area under sunflower in Karnataka and Maharashtra have been due in part to sustained extension efforts. In Orissa, marginal paddy lands are being brought under oilseeds and pulses. Wherever extension advice on the kind and quantity of fertilizers to be used has been linked with a soil analysis service, the efficiency of fertilizer use has increased and the total cost of fertilizers to the farmers has also tended to come down.

The experience gained thus far with the running of a professional extension system has shown that establishment and strengthening of the system requires strong central support and guidance. This is sought to be provided through the National Agricultural Extension Projects (NAEP).

With the twin objectives of combining conservation strategy with the socio-economic needs of the country, soil and water conservation programs have been implemented. The programs for the restoration of fallow land (other than current fallows), the formulation of national policy for conservation, management and development of the land resources of the country, all India soil and land use survey, soil conservation in the catchment river valley projects, integrated watershed management in the catchments of flood-prone areas, and the control of shifting cultivation are some of the major thrusts under the soil and water conservation programs.

The policy of the Government of India is to ensure timely and adequate supply of credit for agricultural operations, with particular emphasis on the requirements of small and marginal farmers and other weaker sections of the society. For this, a multi-agency approach encompassing cooperatives, commercial banks and regional rural banks has been adopted.

A large number of crop-oriented, watershed management, and rural development programs have been launched to benefit the small and marginal farmers in the arid and semi-arid tropics of India.

## 2.2 Evolution of the national research system

The Department of Agriculture of the central government was created in 1891. In recognition of the importance of agricultural research for development, the Indian (then called Imperial) Agricultural Research Institute (IARI) was established at Pusa in Darbhanga District of Bihar in 1905. It was later moved to a site near New Delhi. Most of the state departments of agriculture were established at the beginning of the twentieth century.

The Indian Council of Agricultural Research (ICAR) was created during 1929 as the result of the recommendations of the Royal Commission on Agriculture. Early efforts by the British to improve agriculture in India were prompted by the need to export wheat, cotton, jute, tea and industrial raw materials. Large-scale devastation caused by recurrent famine led the famine enquiry commission to recommend "scientific agriculture for permanent improvement in agricultural production and sustained growth." Independence and partition of the country in 1947 were followed by a period of consolidation and further development of the research system.

Agriculture is a state subject in India. The federal Ministry of Agriculture has to play a coordinating role but, more importantly, it has to take initiatives by way of launching new policies, new programs and new structures which are sensitive and responsive to field problems and demands. Continuous effort is made to sensitize, energize and inspire people and organizations and to simplify the administrative procedures and practices.

The Ministry of Agriculture is basically divided into the Department of Agriculture and Cooperation and Department of Agricultural Research and Education. The Departments of Food, Rural Development and Irrigation which until recently were under the Ministry of Agriculture have been separated out to form independent ministries to reflect their growing importance.

The Department of Agriculture and Cooperation is responsible for formulation and implementation of national policies and programs aimed at achieving rapid agricultural growth through optimum utilization of the country's land, water, soil, plant, animal, dairy, forestry and fisheries resources.

The Department of Agricultural Research and Education provides necessary governmental linkage to the Indian Council of Agricultural Research for dealing with various Central and State Governments as well as with international organizations. The Indian Council of Agricultural Research (ICAR) is the national body responsible for coordinating research, education and extension education in Agriculture, Animal Husbandry and Fisheries Sciences.

The ICAR directly supports 35 Central Institutes, three national research centers, five Project Directorates, and 63 All India Coordinated Research Projects and about 475 ad hoc research projects. The ICAR promotes and supports research through a national grid of cooperative research in which Central Institutes and Agricultural Universities in different states participate as equal partners.

By the year 1983 twenty-three Agricultural Universities were established in different states of the country. All the universities have faculties of agriculture, while most of them also have faculties of animal husbandry and veterinary sciences, agricultural engineering and home science. These universities have 102 constituent colleges and have the annual capacity to produce 8,330 bachelors, 2,824 masters and 717 doctorates.

The universities perform three major functions of education, research, and extension education in an integrated manner. Agricultural universities established through State Acts receive most of their financial support from the respective states. ICAR provides financial assistance to each university as a Development Grant. The direct involvement of ICAR in education is at higher level of learning through the Indian Agricultural Research Institute, the Indian Veterinary Research Institute and the National Dairy Research Institute which run courses at graduate and post-graduate levels.

The National Academy for Agricultural Research Management trains new agricultural research service recruits for assuming leadership in the field of agricultural research. Extension education programs of ICAR that supplement

state extension activities are carried out through National Demonstrations, Operational Research Projects, Krishi Vigyan Kendras and the Lab to Land Program. These first line demonstrations of improved technology provide training of farmers and direct contact between ICAR researchers and extension functionaries and others.

### 2.3 Number and academic training of professional staff

CA

Approximately 6,000 scientists of various categories are employed by the ICAR. Categories S and S<sub>1</sub> with 116 and 2,735, respectively, are junior scientists (fresh recruits) with a minimum M.Sc. or Ph.D. qualification. After every 5 years of research work, their performance is assessed and they are promoted to the higher levels as a part of a career advancement personnel policy for the scientists in ICAR. In 1983-84 there were 1,400 at the S<sub>2</sub> level, 580 at the S<sub>3</sub> level and 75 at the S<sub>4</sub> level. The All India Coordinated Research Project on Dryland Agriculture established in 1970 has 23 centers representing major agro-climatic zones in the country with its headquarters at Hyderabad. The project has 468 professionals with a budgetary provision of 20 million rupees during the Sixth Plan (1980-85).

All India Coordinated Research Projects, for sorghum, millets, pulses and oilseeds employ 168, 207, 754 and 168 scientists, respectively, with budgetary provision of 12, 13, 45 and 15 million rupees for the Sixth Plan period. The last-named three projects also include crops other than pearl millet, chickpea, pigeonpea and groundnut. The budgetary provision had increased from 300 to 500 percent over the period of three 5-year plans.

In addition to those in ICAR, approximately 8,000 scientists work in the agricultural universities in teaching, research and extension education, where each is required to perform at least two functions out of the three. Hence, the number of available researchers far exceeds the 6,000 of ICAR.

#### 2.4 Budget of ICAR

The budget of the ICAR devoted to ICRISAT mandate crops and technologies is given in Table 2.1. The table clearly shows that the budget allocations for research on sorghum, millets, pulses and groundnut have increased by 300 to 500 percent or more, over the past 15 years. This trend has brought research on SAT crops more into balance with needs than had been the case earlier. The budget for millets not only includes pearl millets but also other minor millets, and the budget for pulses not only includes chickpea and pigeonpea but also other rainy season and post-rainy season pulses.

#### 2.5 Achievements of national agricultural research

The national agricultural research system has released many hybrids and varieties of sorghum, pearl millet, chickpea, pigeonpea and groundnut and continues to do so. These varieties were bred for resistance to important diseases and pests or environmental stresses, grain and fodder quality (dual purpose varieties), maturity periods, yielding ability and seasonal, local and regional adaptations. Several aspects of farming systems research and socio-economic studies were also undertaken and tested.

In the 1980-83 period, 18 sorghum varieties and hybrids developed by national scientists have been released, 15 of pearl millet, an early pigeonpea variety (less than 160 days), 19 medium or late pigeonpea varieties, 23 chickpea varieties and 28 groundnut varieties. Most of the sorghum and millet varieties are suited to high input, irrigated conditions.

Table 2.1 Financial Allocation under Selected ICAR

(In million rupees)

| Crop/Commodity<br>or Project | 4th Plan<br>(1970-75) | 5th Plan<br>(1975-80) | 6th Plan<br>(1980-85) |
|------------------------------|-----------------------|-----------------------|-----------------------|
| Sorghum                      | 3.64                  | 8.62                  | 12.00                 |
| Millets                      | 3.60                  | 4.50                  | 13.43                 |
| Pulses                       | 7.73                  | 31.60                 | 44.86                 |
| Oilseeds                     | 4.92                  | 9.01                  | 15.44                 |
| Dryland<br>agriculture       | n.a.                  | n.a.                  | 20.00                 |

n.a. - Not available.

Source: ICAR.

Development of compaction technology (for highly permeable sandy and loamy sandy soils), chisel technology (for soils with high mechanical impedance), raised and sunken bed technology (for slowly permeable flat valley soils), ridge technology (for slowly permeable undulating and rolling topography) and seed line mulch technology (for soils that form crusts) have had significant impacts on crop production.

The "Haveli System" cultivation in black soils of Jabalpur and Narasingpur has been followed by the farmers with success for several decades.

Different crops and cropping systems have been identified for fuller and more efficient utilization of rainfall and stored moisture under different soil profile conditions. Optimal plant populations have been determined for recommended high-yielding varieties and hybrids under different farming situations.

Intercropping is promising during the rainy season and not so promising in the post-rainy season (receding moisture situation) generally. Where double cropping is not feasible for some reason, but rainfall is more than 700 mm per annum, intercropping increases the cropping intensity 40 to 80 percent depending on soil and rainfall characteristics. The concept of "additive" and "optimum population" for both the "companion crops" was developed for the intercropping systems after a series of investigations. It has been extensively demonstrated that almost full yield of the base crop and additional yield of the intercrop could be obtained, resulting in a land equivalent ratio of up to 1.80.

Control measures for major pests, diseases and weeds including genetic, chemical and cultural methods have been developed and widely recommended to and adopted by the farmers.

The organic farming concept was developed and promoted to save energy. The associated practices are crop rotation, crop residues, animal manures, legumes, green manure, off-farm organic wastes, mechanical cultivation, mineral bearing rocks, biological pest control, control of weeds and diseases and use of bio-fertilizers.

The dryland project has shown that rainwater can be harvested successfully in two ways, (a) water harvesting in situ and (b) run-off collection and recycling. Land configuration can increase grain yield by about 15 percent. The pond size for different size holdings or group of holdings, feasible methods to prevent seepage losses in light soils, and efficient lifting devices for run-off management are being worked out. Application of one supplemental irrigation from harvested water results in increased yield of most crops of about 200 percent.

The marginal lands can be managed with agroforestry or agropastoral systems. Subabool (Leucaena leucocephala) and Stylosanthes species are very useful in these systems. The yield of pearl millet, castor and sorghum are increased in association with Leucaena as compared to the yields of the same crop grown pure.

Agrohorticultural systems are similar to agroforestry systems. The trees yield fruit in addition to fuel wood. Zizyphus species, Psidium

guajava, Mangifera indica, Embilica officinalis, etc. can be integrated with crops, legumes and grasses.

In an agropastoral system, the best legumes found to be excellent in high-yield persistence, nutritive value and palatability were Stylosanthes species particularly S. hamata and S. scabra. Besides supplying continuous fodder in drylands, pasture legumes help in the restoration of soil fertility by adding nitrogen and organic matter.

Double cropping (200 percent intensity) is possible within 30-50 week period where rainfall is in excess of 850 mm and profile moisture storage capacity is in excess of 200 mm. For regions with a 20-30 week growing season, cropping intensity can be increased through intercropping in areas where rainfall exceeds 500 mm and profile moisture storage capacity is well above 100 mm.

The soil and water conservation practices recommended are contour farming and the broad bed and furrow (BBF) system on lands having slopes up to 3 percent, bunding, graded bunding and contour ditching with slopes of 3-6 percent, bench terracing on hill slopes of 6-33 percent and run-off harvesting in cropped lands.

Widening plant rows without reducing plant population does not reduce yields but it saves energy and helps to cover larger areas for a given rainfall event. By adopting off-season tillage, the available bullock resources can be used efficiently over time to cover more area for land preparation.

For black soils, an improved blade or bakhar has been designed which minimizes frequency of cleaning of the blade and is to a great extent self sharpening. The draft is also reduced. One-row seed and fertilizer drill has been developed for sowing of both smaller and larger grain crops. The implement costs approximately Rs. 300 and covers 0.4 hectare per day at 45-cm row spacing.

The animal drawn multipurpose tool carrier (tropicultor) is being extensively field evaluated for its suitability for doing various field operations under black soil conditions but it requires a large investment (about Rs. 14,000) and its widespread use by the individual farmer without governmental support is limited.

Some of the factors responsible for differences in yield obtained at experimental stations, verification trials, demonstrations and by the farmers are cost-intensive technology, absence of adequate information on graded or intermediate technology to suit the farmers of varying resources, subsistence economy of the farmers, difficulties in procuring inputs, pricing structure and marketing behavior.

Lessons from the dryland operational research project indicate that nearly one-third of the available recommendations have not been found to be suitable under dryland farmers' management conditions, in spite of the fact that they continue to give desirable results at the research stations. Hence these have provided useful feedback for future research, e.g., striga problem in sorghum hybrids, root wilt in castor, grain mold and root wilt in chickpea, and root wilt and pod borer in pigeonpea.

### 3 Collaborative Activities of ICRISAT with the National System

#### 3.1 Collaboration

In 1972, a memorandum of understanding was executed between the Government of India and the Ford Foundation on behalf of the CGIAR for the establishment of ICRISAT as a world center for research on sorghum, millet, chickpea and pigeonpea in India. In 1975, groundnut was added to this mandate. The Indian Council of Agricultural Research, the apex body of agricultural research in the country, was named as the link organization for the agreement. To strengthen the linkage further, ICAR and ICRISAT entered into a supplemental agreement in 1976. Within the framework of the mandate of ICRISAT as approved by the Board of Governors and the CGIAR the institute is required to assist in the development and transfer of technology to the farmer through cooperation with the national and regional research programs and by sponsoring workshops and conferences, operating training programs and assisting extension activities.

Unlike many other developing countries, India had a strong network of research organizations much before the establishment of ICRISAT. Because of the establishment of a large number of state agricultural universities, the number of trained scientists to handle various research programs in the country was adequate to manage the various projects. ICRISAT has been fortunate to be able to hire large numbers of national scientists and obtain access to the existing large germplasm collections from the All Indian Crop Improvement Programs. This, by itself, is an indicator of collaborative work between ICRISAT and the national research system of India.

At the highest level, the Director General of ICAR and the Secretary to the Government of India in the Department of Agricultural Research and Education, the Secretary of Agriculture, Government of India and the Chief Secretary of the State of Andhra Pradesh are all members of the Governing Board of ICRISAT. This provides a good linkage of ICRISAT to national authorities on agricultural research and extension. The Government of India, on the recommendation of the ICAR-ICRISAT Policy Committee, authorized ICRISAT to develop cooperative Research Stations at Anantapur, Bhavanisagar, Dharwad, Gwalior and Hissar.

Collaboration between ICRISAT and the national system is mainly through the free flow of genetic materials, research information, planning and designing of research investigations, development and testing of new research methods and the enhancement of human capital.

ICRISAT identified four areas of challenges toward which its program is aimed. They are (1) environment-based problems, (2) socio-economic conditions, (3) crop improvement and (4) farming systems for the farmers of semi-arid tropics of the world, where, for generations the world's rural poor have lived with insecurity and unpredictable harvests and a fear of periodic food shortage.

Because of the strong national research and extension programs, a good number of crop varieties and hybrids of millets, pulses and oilseeds, the dominant crops in these inhospitable and harsh environments, were not only developed and widely tested but were being grown extensively by farmers before the establishment of ICRISAT. Dryfarming research which started in India as

early as 1923 and was intensified in the 1970s was, in some ways, a forerunner of farming systems research in India. This shows the importance of the perceived problems of dryland farmers and the forward looking policies of Indian agriculture. With the establishment of ICRISAT, the farming systems approach achieved greater prominence in the national (and international) programs.

It is in this context that the conclusions below were drawn. ICRISAT is only 14 years old. This is too short a period to study its impact on farmers though it is a reasonably good period for study of its impact on the national research system. This chapter examines those direct contributions of ICRISAT. In the next chapter the effect of the collaboration between the national system and ICRISAT on farmers is examined.

### 3.2 Flow of information

ICRISAT publishes annual reports, bulletins, conference, seminar and symposia papers, newsletters, folders and handouts for wide circulation among research workers around the world. Similarly, the publications of the national system are made available to the ICRISAT scientists.

Flow of information is also ensured through personal communications, field visits, participation in workshops of the All India Coordinated Research Projects of ICRISAT mandate crops and technologies, and training programs for upgrading capacities of national scientists.

### 3.3 Distribution of germplasm

The germplasm of sorghum, pearl millet, pigeonpea, chickpea, groundnut and minor millets that have been collected from India and other SAT areas are widely distributed free of cost among Indian national research program scientists on request. The annual germplasm distribution by the Genetic Resources Unit of ICRISAT from year 1974 till the end of the year 1983 to Indian scientists and institutions is summarized in Table 3.1.

The table clearly shows that Indian scientists have taken extensive advantage of the germplasm bank maintained by ICRISAT. The germplasm of pearl millet was in good demand between 1975 and 1980 and that of chickpea and groundnut between 1980 and 1983. The demand for germplasm of sorghum and pigeonpea was maintained throughout the 9-year period from 1975 to 1983. Work on groundnut at ICRISAT started late 1975-76 as compared to other crops which started as early as 1972-73. Indian scientists have also shown deep interest in minor millet research, as evidenced by the numbers of materials distributed by ICRISAT even though the institute does not yet conduct research on minor millets.

The germplasm samples of mandate crops collected and assembled from Indian sources are shown in Table 3.2. From 1973 to 1984 India contributed significantly to the germplasm pool. Some of the Indian scientists who had large collections of germplasm shared them freely with ICRISAT.

ICRISAT's role in collection, preservation, evaluation and utilization and finally distribution of germplasm among Indian scientists, in particular, and the SAT region of the world, in general, is commendable.

Table 3.1 ICRISAT Germplasm Distribution in India (1974-83)

| Year | Sorghum | Pearl Millet | Pigeonpea | Chickpea | Groundnut | M. Millet |
|------|---------|--------------|-----------|----------|-----------|-----------|
| 1974 | 3       | 75           | 14        | 695      | -         | -         |
| 1975 | 2102    | 1179         | 290       | 837      | -         | -         |
| 1976 | 1788    | 2327         | 3498      | 1990     | -         | -         |
| 1977 | 2841    | 1518         | 760       | 203      | 645       | -         |
| 1978 | 2159    | 2846         | 1203      | 375      | 995       | 2721      |
| 1979 | 3720    | 3134         | 1487      | 619      | 1835      | 3920      |
| 1980 | 1798    | 1359         | 1213      | 2091     | 2343      | 1345      |
| 1981 | 3571    | 525          | 2524      | 3404     | 2106      | 3344      |
| 1982 | 1430    | 569          | 1356      | 4818     | 3218      | 2080      |
| 1983 | 3415    | 560          | 1597      | 4200     | 1210      | 212       |

Source: ICRISAT Genetic Resources Unit.

Table 3.2 Germplasm Samples of ICRISAT Mandate Crops Collected and Assembled\* from Indian Sources (1973-84)

| Year            | Sorghum     |            | Pearl Millet |             | Pigeonpea   |             | Chickpea    |             | Groundnut   |            |
|-----------------|-------------|------------|--------------|-------------|-------------|-------------|-------------|-------------|-------------|------------|
|                 | Assembled   | Collected  | Assembled    | Collected   | Assembled   | Collected   | Assembled   | Collected   | Assembled   | Collected  |
| 1973            | -           | -          | -            | -           | 3283        | -           | 6138        | -           | -           | -          |
| 1974            | -           | -          | 3792         | -           | 431         | 134         | 485         | -           | -           | -          |
| 1975            | 8961        | -          | -            | -           | 286         | 289         | 303         | 136         | -           | -          |
| 1976            | -           | 183        | 314          | -           | 387         | 329         | 129         | 224         | 1926        | 28         |
| 1977            | -           | 36         | 142          | 464         | 6           | 297         | 9           | 182         | 2981        | 128        |
| 1978            | 365         | 34         | 3117         | 1094        | 753         | 228         | 4           | 65          | 5           | 161        |
| 1979            | -           | 268        | 1121         | 486         | 746         | 138         | 49          | 160         | 66          | 102        |
| 1980            | 15          | 218        | -            | 163         | 10          | 24          | 4           | 176         | -           | -          |
| 1981            | 93          | 109        | -            | 127         | 2           | 183         | 56          | 4           | 9           | 184        |
| 1982            | -           | -          | -            | -           | -           | 20          | 28          | 47          | -           | -          |
| 1983            | -           | -          | -            | 204         | 504         | -           | 8           | 50          | 1           | -          |
| 1984<br>(Sept.) | -           | -          | -            | 113         | -           | 195         | 2           | -           | -           | -          |
| <b>Total</b>    | <b>9434</b> | <b>848</b> | <b>8486</b>  | <b>2651</b> | <b>6408</b> | <b>1837</b> | <b>7215</b> | <b>1044</b> | <b>4988</b> | <b>603</b> |

\*Assembled germplasm may or may not include germplasm collected from other countries.

### 3.4 Enhancement of human capital

ICRISAT provides educational opportunities and session-long practical experience in field research at the institute. The objective of the training is to make agriculturists more efficient in research, training and extension programs in the rainfed and semi-arid tropics. The training program at the institute provides for an increasing number of skilled scientific, technical and service personnel to assist in improving crop production. The training program links national, regional and international research and development of the SAT with ICRISAT's scientific expertise, germplasm resources and research facilities that are not readily available, especially for African researchers.

The Indian participants in training programs consisted of in-service trainees, research fellows, scholars and interns. The ICRISAT training is aimed at water management, intercropping and sequential and relay cropping and the new concepts of farming systems research. The former trainees seek continuing contact with ICRISAT scientists to keep up with research news and comments. Table 3.3 provides data on Indian trainees.

### 3.5 Non-CGIAR assistance relating to agricultural research

ICRISAT is far from being the only non-national agricultural research effort in India. Some of the other major outside assistance efforts that contribute to the development or improvement of agricultural research capacity in the country are mentioned briefly.

**Table 3.3 Number of Indian Scientists Participating in Training Programs Conducted by ICRISAT during 1974-1983**

| Discipline         | Category of Trainee |           |                  |                 |                  | Total      |
|--------------------|---------------------|-----------|------------------|-----------------|------------------|------------|
|                    | Apprentice          | Inservice | Inservice Fellow | Research Fellow | Research Scholar |            |
| Biochemistry       | -                   | -         | -                | 1               | 3                | 4          |
| Crop improvement   | -                   | 17        | -                | 6               | 5                | 28         |
| Entomology         | -                   | 14        | -                | 1               | 5                | 20         |
| Farm mechanization | 11                  | -         | -                | -               | -                | 11         |
| Farm development   | 18                  | -         | -                | -               | -                | 18         |
| Microbiology       | -                   | 19        | -                | 2               | 6                | 27         |
| Pathology          | -                   | 32        | 4                | 5               | 7                | 48         |
| Physiology         | -                   | -         | -                | 5               | 3                | 8          |
| Socio-economics    | 2                   | -         | -                | -               | 6                | 8          |
| Soils              | -                   | 11        | -                | -               | -                | 11         |
| Others             | 8                   | 3         | 1                | 5               | 15               | -          |
| <b>Total</b>       | <b>39</b>           | <b>96</b> | <b>5</b>         | <b>25</b>       | <b>50</b>        | <b>215</b> |

Source: ICRISAT.

IDA. The National Agricultural Research Project is the first major effort of ICAR to upgrade and strengthen the regional research capability of the state agricultural universities. The project is designed to fill gaps in research and also to meet the needs of the extension services and farmers as far as the new and proven technologies generated through applied research addressed to specific localized constraints in agricultural production are concerned. Launched on January 1, 1979, the project is funded by the ICAR, and is supported by IDA, the soft loan affiliate of the World Bank, to the extent of \$27.0 million (about 50% of the total expenditure). The closing date of the project, which was September 1983, was extended to September 1985 at the Government of India's request.

CIDA. The Canadian Government has been supporting the research, operational research projects and transfer of technology programs connected with dryland agriculture in India through ICAR.

FAO/SIDA. FAO of United Nations and the Swedish Government through SIDA have been sponsoring training programs on maize and millets for the developing countries through ICAR/IARI once every 2 years.

UNDP. The United Nations Development Program has been supporting the implementation of a project for agricultural education and research for accelerated agricultural development for 7 years starting from October 1, 1983.

USAID. A project grant agreement for Indo-U.S. collaboration with \$20 million assistance from USAID and the equivalent of \$8 million as Government of

India's counterpart contribution allocated for agricultural research in the priority areas identified by the Indo-U.S. subcommission on agriculture has been signed, incorporating modalities of operation, implementation of the projects, their funding and monitoring.

Detailed projects have been formulated thereunder for (i) soybean processing and utilization; (ii) post-harvest technology for fruit and vegetables; and (iii) groundnut research. The last named project has been deferred for implementation.

PL 480. About 53 research projects in operation at various institutes and agricultural universities covering almost all fields of agricultural research are being supported with funds generated by the sale of donated food commodities under Public Law 480 of the United States.

#### 4 The Contributions of the Collaboration

ICRISAT's primary responsibility is research; there are other organizations which have a primary responsibility for institution building. The urge for immediate impact on, for example, small farmers, by donors to the CGIAR may prove adverse to building a strong base of knowledge through basic and mission-oriented research to overcome some of the more difficult problems and to develop new methods to accelerate the pace of scientific advance. A less appropriate but much sought after measure of impact is the value of increased food production that has resulted from the research findings of ICRISAT. Because progress in agriculture is governed by natural growth processes, it takes time and, since ICRISAT is a young institution, it is unlikely that very much of its scientific work has yet had significant impact on food production.

ICRISAT's contribution to increased agricultural production depends on complementary activities such as the adoption and dissemination of technologies by other institutions such as the National Research Institutes of the Ministry of Agriculture and the State Departments of Agriculture. Any impact from new technologies that ICRISAT has helped to develop cannot be attributed solely to ICRISAT. In fact, ICRISAT does not directly release varieties or production technologies to the farmers. National researchers and the national and state governmental authorities are responsible for these tasks.

The activities of ICRISAT have been varied and relate to a wide range of problems facing agriculture in the semi-arid tropics of India. The

main contributions of ICRISAT have been in the development of research methods for crop breeding, agricultural economics and farming systems research and in the development of varieties and other innovations which are now beginning to reach farmers' fields.

#### 4.1 Contribution to research methodology

The details of achievements of ICRISAT contributions to research methods are discussed under four categories: (a) environment-based problems; (b) socio-economic conditions; (c) crop improvement; and (d) farming systems.

Environment-Based Problems. Mathematical models permitting analysis of probabilities of establishing successful crops in specific locations showing the length of growing seasons and amounts of soil and water needed for raising specific crops have been developed. These models can guide farmers in selecting crops with the correct growing period in relation to moisture in the soil. Crop-growth modeling has been used to highlight areas of risk associated with dryseeding crops before the rains begin. Suitability of crops for intercropping, relay and sequential cropping has been identified. The national system has a broader spread of accomplishments in this regard because of the large number of centers working on the subject and the greater number of locations available for identifying location-specific technologies.

Socio-economic Conditions. Socio-economic research at ICRISAT has shown that there is little significant difference in the willingness of small and large farmers to take a chance on new cultivars. Therefore, it is more important that all farmers have an opportunity to get good quality seed at attractive

prices than to attempt to breed special low risk strains aimed at small farmers.

Breeding strategies for sorghum and millets must emphasize high and stable yields as well as cooking and eating qualities which the consumers value.

Farmers will organize and cooperate to improve drainage on a watershed basis. Ponds for recycling run-off on small watersheds seem best suited to use by individual farmers. Facilities for supplementary irrigation, such as wells, can be profitable enough to attract small groups of farmers since wells can be operated according to simple rules that make long-term shared ownership and use practical.

Women are particularly important workers in SAT, where weeding is one of their main farming activities. New technology offers opportunity to the female work force for better employment and higher income.

Crop Improvement. Plant diseases, destructive pests and parasite weeds are the relentless enemies of farmers in SAT and the rest of the people who depend on farmers for food. Low and unstable crop yields are due to environmental and biological stresses. ICRISAT aims at crop improvement through the following methods and techniques:

- a. utilization of genetic resources in construction of new varieties and hybrids with enhanced yield potential and stability to environmental hazards;

b. utilization of farmers' traditional cultivars (many of which are threatened with extinction) that show specific genetic characteristics to resist the hazards of the natural environment;

c. evaluation of germplasm at or near the place of collection permitting more accurate assessment than testing outside the crop's natural adaptation area;

d. development of improved and reliable techniques for routine large-scale screening of germplasm and breeding lines for their ability to resist diseases;

e. distribution of disease-resistant breeding materials and field-tested technologies for further selection by the national scientists;

f. development of the screening technique for multiple disease resistance in one generation in pearl millet;

g. development of white seeded sorghum lines with reduced susceptibility to grain mold and with high resistance to sorghum downy mildew; and

h. development of the 'sick' plot technique to screen for resistance to pigeonpea wilt.

Farming Systems. According to ICRISAT, the SAT farmers plant long-duration crop varieties that give adequate vegetative growth in good years but low

**grain yields. They struggle to raise crops in soils with poor physical conditions, waterholding capacity and fertility and are not able to effectively manage deep vertisols or to afford improved seeds, fertilizers, plant protection chemicals and implements. Existence is precarious, especially in those years when crops fail or produce little because of drought, pests and disease. ICRISAT aims at farming systems improvement through the following methods and techniques:**

**a. development of improved drainage and planting methods in a broad bed and furrow technology to facilitate cropping during the 180-200 growing day phase on heavier soils;**

**b. development of an improved intercropping system for lighter soils;**

**c. development of the concept of watershed units for improved management of soil, water and crop production consistent with soil conservation principles;**

**d. development of deep vertisol technology as a total package;**

**e. development of an alfisol technology;**

**f. "on-farm" testing of the ICRISAT mandate crops and technologies;  
and**

**g. "operational research".**

ICRISAT has always identified the priority of research problems on its mandate crops and farming systems through reviews in specially designed international seminars involving national scientists. Based on the conclusions drawn from such seminars, ICRISAT plans its research strategy within and outside the country.

ICRISAT has entered into memoranda of understanding with ICAR and several state agricultural universities through whom cooperative research stations have been developed. These include Anantapur for drought resistance studies on all crops except chickpea, Bhavanisagar for sorghum and pearl millet, Dharwad for sorghum and groundnut, Gwalior for long duration pigeonpea and chickpea, and Hissar for chickpea and short duration pigeonpea and pearl millet. At the latter four, on a south to north axis, ICRISAT collaborates on crop improvement in climates different from that at Patancheru (Hyderabad) but similar to those in parts of the African, Asian and Latin American SAT.

ICRISAT has also been doing "on-farm" studies and "village level studies" in collaboration with the Departments of Agriculture and agricultural universities, respectively.

In some of these, ICRISAT staff are directly posted to the project centers while in others special staff are hired by a university with ICRISAT funding. In still others, ICRISAT has been working through the Department of Agriculture in the Government farms or on farmers' fields.

The observations of the authors, based on discussions with many universities and Departments of Agriculture personnel, of ICRISAT's impact at these centers and on farmers' fields are:

a. the scientists of the agricultural universities located at the same center are generally not involved in the planning and execution of the research programs;

b. the scientists of ICRISAT and the agricultural university working at the same location are sometimes not aware of each other's technical program;

c. the agricultural universities tend to feel ignored when work is done by ICRISAT directly on farmers' fields through the departments of agriculture in the states; and

d. there is no clear-cut policy of conducting adaptive research on farmers' fields before going in for operational research.

Some of the present less-than-satisfactory situations may not be intentional on either side but, to avoid confusion in the future a clear-cut policy must emerge.

In the authors' view, ICRISAT should always operate through ICAR institutes, All India Coordinated Research Projects and agricultural universities in its research on farmers' fields. It is up to the agricultural universities to work through the Departments of Agriculture of the states in which ICRISAT could and should play an advisory role.

The ICRISAT scientists located at the university centers should ensure that they are not unfamiliar with the system. The local university scientists should be involved in ICRISAT's research activities for mutual benefit.

The linkage between the national research system and ICRISAT is in general very good. All the scientists working on ICRISAT mandate crops and technologies in the national system are invited by ICRISAT to participate in seminars, conferences and workshops of their interest and specialization. They also participate in selection of breeding material and organize and conduct tours.

ICRISAT scientists are also invited by the Project Directors and Project Coordinators of sorghum, millets, pulses, oilseeds and dryland agriculture projects to participate in their workshops and planning meetings.

#### 4.2 Significant innovations of the national system and ICRISAT

Varieties. A large number of varieties and hybrids of sorghum, pearl millet, chickpea, pigeonpea and groundnut are recommended for release in the annual workshop of the respective All India Coordinated Crop Improvements Projects of ICAR and released by the Central Variety Release Committee based on the data on multilocation tests and minikit trials for multiplication of seeds by the National and State Seed Corporations and distribution among farmers. The varieties and hybrids developed at ICRISAT and in the breeding programs of agricultural universities, besides those of the coordinating centers, are considered in the same meeting for pre-release and subsequent release of varieties.

ICRISAT's SPV 351 was among the three sorghum varieties (the others were SPV 346 and SPV 245) recommended for pre-release seed multiplication and minikit trials on farmers' fields in 1981. All three possess good grain quality and multiple resistance to grain molds, leaf spots and downy mildew. ICRISAT's SPH 221 and SPV 475 were identified in the 1984 workshop for seed multiplication and minikit demonstration.

Two important sorghum growing states, Maharashtra and Karnataka, use hybrid sorghum on nearly 70 percent of the total sorghum area. How far the newly released SPV 351 variety will succeed for hybrid growing areas is yet to be assessed. SPV 475, SPV 386 and SPH 221 were in the minikit in 1984. SAR 1 and SAR 2, two striga resistant lines, are doing better than locals in light red soils where striga is a problem. None of these are higher yielding than the good existing hybrids. In heavy soils and high moisture conditions, striga is not an important problem. The line PM 11344 has been identified to be midge resistant in endemic areas represented by Dharwad.

ICRISAT's WCC 75 variety (providing 98 percent of the grain yield of JB 104) was recommended for general cultivation in 1982 along with BD 763, MBH 110 and CM 46, and final testing of MH 34, MH 36, MH 60, MH 62 and MH 65 which had 3.3 to 14.3 percent higher yield than the standard BJ 104. ICRISAT's pearl millet synthetic ICMS 7703 (MP 15) and ICH 241 (MH 65) entered into minikit in 1982 along with others from national research activities.

None of ICRISAT's pigeonpea varieties yet has found a place in the all India list. One of the states (Himachal Pradesh, not important for pigeonpea cultivation) has released an ICRISAT line under the name HPA 92.

ICPL 1 and ICPL 6 are purer forms of UPAS 120 and T 21 developed by ICRISAT, having comparable yields of their original parents. ICRISAT materials ICPL 151 and ICPL 270 were found to be promising in the 1983-84 rainy season for the Central Zone and Peninsular Zone, respectively.

ICRISAT's chickpea line ICC-4 though released in Gujarat state, was not in the all India list of released and pre-released varieties of chickpea during the years 1980-83. Many of the ICRISAT lines, however, have shown useful resistance to pests and diseases.

Methods. ICRISAT has developed the concept of watershed units for improved management of soil, water and crop production consistent with good soil conservation principles. These principles have been accepted and vigorously adopted by the Government of India as the basis of dryland improvement.

ICRISAT has improved the methods for screening sorghum germplasm against grain mold, downy mildew, striga and midge. The checkerboard technique developed for testing sorghum lines against striga resistance is now being used by national scientists. That method of screening sorghum lines against midge is a definite contribution.

Large-scale field screening techniques for pearl millet have been developed and used to screen for downy mildew (Sclerospora graminicola) ergot (Claviceps fusiformis) and smut (Tolyposporium penicellariae) in one generation.

The wilt disease of chickpea which baffled Indian pathologists for over 40 years has been demonstrated to be incited by a number of pathogens. Resistance has been identified for Ascochyta, Botrytis, anthracnose, root rots, stunt virus, wilt, pod borer, either singly or in combination of two or three. A large number of lines have been identified possessing a considerable measure of tolerance to soil moisture stress, iron deficiency and genetic variability for ability of seeds to germinate under limited seed bed moisture. The screening methods developed cover resistance to wilt, dry root rot, Ascochyta blight, Botrytis, gray molds, cyst nematodes, Orobanche pests, pod borer, leaf miner, grain quality, drought, cold, iron deficiency, salinity and reaction to photoperiod.

In pigeonpea ICRISAT has developed screening methods for wilt, Phytophthora blight, Alternaria blight, bacterial blight, sterility mosaic, yellow mosaic diseases, pod borer and pod fly pests, reaction to drought and waterlogging and grain quality. Numerous resistant lines of pigeonpea have been identified for resistance to wilt, Phytophthora blight, and Alternaria blight. The etiology of sterility mosaic has been further clarified.

Other Research Findings. Some of the economic studies taken up at ICRISAT have influenced the policy decisions of the Government of India. One example is the study of tractorization by Binswanger. This study showed that use of tractors resulted in displacement of labor and did not either increase yield or cropping intensity. To discuss the report of the study, a meeting was called by the Planning Commission, Government of India, to which senior officers of the Department of Agriculture, Government of India, and Indian Council of Agricultural Research were invited. There were lots of arguments

for and against the conclusions of the study. Ultimately a decision was taken by the Planning Commission not to support the request of a state to allow the import of combine harvesters and threshers for the harvest of wheat.

Food grains contribute most of the food energy and significant portions of vitamins, protein and minerals for farmers and their families in the region but consumption is much too low. To fill the critical gaps, breeding strategies for sorghum and millets must emphasize nutritional quality in addition to high and stable yield. Most sorghum and pearl millet is produced and consumed in the same area with small marketable surplus (22 to 26 percent), while 35 percent of pigeonpea, 45 percent of chickpea and 80 percent of groundnut are traded.

ICRISAT research has shown that institutional credit is concentrated in the hands of richer farm households whose members are better educated, are older and have larger farms and more family members. Borrowers often succeed in diverting credit from the stipulated purpose to another purpose. Defaulting on institutional loans is widespread but is rare for informal credit; unless payment discipline is improved, it will be extremely difficult to transfer technological packages successfully.

Single commodity crop insurance programs neither generate large stability benefits nor protect households from abrupt shortfall in income. Public works programs are a better bet to stabilize income because they select the needy, particularly the women. The overwhelming majority of both small and large farmers are at least moderately averse to risk.

High-yielding varieties, inorganic fertilizers and improved soil and crop management practices were the major ingredients of technology contributing to economic profits.

WCC 75 and ICMS 7703, two pearl millet varieties of ICRISAT that are resistant to downy mildew and ergot, have similar grain yields to those of BJ 104 and BK 560, but have 20 percent higher fodder yield. WCC 75 has been released for general cultivation, while ICMS 7703 has been released in Maharashtra state.

Harvesting, storing and recycling water to produce low-value upland crops like sorghum alone cannot be justified. But, intensively managed crops like pigeonpea planted at high stands might allow the real potential of supplementary irrigation to express itself. Several watershed-based technology options require group action for their adoption.

Vertisol technology, as developed by ICRISAT, is location specific and has to be tailored to the individual location, soil and rainfall characteristics. Its adoption depends on availability of the tractor for broad bed and furrow and drainage development, and production or at least land shaping on a community basis. Modified forms of the technology are being tested on a pilot scale in Karnataka, Andhra Pradesh, Maharashtra and Madhya Pradesh by the concerned Departments of Agriculture. Improved drainage and planting methods using the BBF technology facilitates cropping for 180-200 days, compared to about 100 days with conventional methods, raising the crop production from 500 to 3,000 kg/ha/year.

The most promising system for deep black soil is the cereal plus pigeonpea intercrop which is stable and attractive because it avoids the problem of having to establish the second crop when the upper soil layers may be dry and when the workers are busy harvesting rainy season crops. An intercropping system combining early maturing cereals and legumes with later maturing deep rooted pigeonpea or castor has ensured efficient use of both the rainy period and residual soil moisture in lighter soils. Sorghum plus pigeonpea and groundnut plus pigeonpea have been found to be efficient intercrops. A sorghum intercrop markedly reduces the soil borne wilt disease of pigeonpea and an intercrop of sorghum or millet has given small but consistent decrease in the rust incidence of groundnut.

The broad bed and furrow technology developed by ICRISAT's farming system program permits farmers to harvest two crops where one is traditionally harvested. Pilot trials were run in 8 locations in 1982, 30 in 1983 and 40 in 1984, in four states, namely Andhra Pradesh, Karnataka, Maharashtra and Madhya Pradesh. The total area covered by the BBF technology in 1984 is estimated to be about 4,000 hectares. This technology, if it succeeds, may be suitable for an estimated area of 5 million hectares.

Deep vertisol soils are difficult to cultivate using conventional bullock-drawn implements in India. ICRISAT assisted in developing a wheeled tool carrier (tropicultor) that was made available to the farmers in 1979. The machine facilitates the construction of the broad beds and furrows and can be used for planting, cultivation and other operations. It is relatively expensive and so financial institutions and the governments have included this aspect in the pilot BBF projects. It is estimated that 600 wheeled tool carriers were produced in India in 1983.

On-farm tests of the deep vertisol technology compared to farmers' traditional practices in seven villages between 1979-80 and 1982-83 have helped identify the ecology for which the technology is most suited.

It is difficult to estimate the likely future impact with any assurance at this stage because of several scientific and policy related issues to be decided by the Government of India, NARS, state governments and ICRISAT.

#### 4.3 Assessment of ICRISAT by NARS scientists

The linkage between ICRISAT and the national research system is very good based on the response of a sample of scientists responding to a questionnaire that was part of the study. All the scientists working on ICRISAT mandate crops and technologies in the national system are invited by ICRISAT to participate in seminars, conferences and workshops of their interest and specialization. ICRISAT scientists are also invited by the Project Directors and Project Coordinators of sorghum, millets, pulses, oilseeds and dryland agriculture projects to participate in their workshops and planning meetings.

A majority of the national scientists are aware of the CGIAR and international agricultural research centers. Two-thirds of the respondents felt that ICRISAT's efforts were complementary, but one-fourth felt that they were competitive in the development of finished products especially crop varieties/hybrids.

One-half of the number of respondents rated the quality of service of ICRISAT as 'very good', 40 percent rated it as 'good' and the rest as 'fair'.

Regarding the impact of innovations developed by ICRISAT on food production, the Director of Research, A.P.A.U. has stated that ICRISAT's pearl millet variety WCC-75 is widely accepted by farmers in Andhra Pradesh. A senior scientist from Maharashtra has reported that an ICRISAT pearl millet variety covers about 5 percent of the crop area. About one-sixth believe that the varieties have been too recently released to evaluate. About one-fourth have stated that no information is yet available. Some have not made any comment and a few have reported insignificant or no impact.

A majority of the respondents expect ICRISAT to play a very useful role in the future by training the trainers as well as by developing new research methods. To quote the Director General of ICAR "I must say that our working relationship with ICRISAT has been most rewarding. In the future, we shall have to guard zealously against possible duplication between national and international research efforts. We certainly look to the international scientific community for more basic and mission-oriented research to overcome some of the more difficult problems and develop new methodologies to accelerate the pace of scientific advance."



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