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FARMING SYSTEMS RESEARCH PROGRAM AT ICRISAT : AN OVERVIEW(1)

(1) : This paper has been prepared by the Farming Systems Research Program staff, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru P.O., Andhra Pradesh 502 324, India.

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FARMING SYSTEMS RESEARCH PROGRAM AT ICRISAT : AN OVERVIEW[1]

In recognition of the need to improve the well-being of the people of the semi-arid tropics (SAT) and to bridge the ever-widening gap between food production and demand, the Consultative Group on International Agricultural Research created ICRISAT in 1972. The institute has a global responsibility for crop improvement research in sorghum, millet, chickpea, pigeonpea and groundnut. It has a special mandate for research in farming systems, socioeconomic constraints, and transfer of technology for the seasonally dry SAT, to catalyze a breakthrough in the agricultural production of the region.

This paper has been prepared for the OAU workshop on Farming Systems. It is intended to give an overview of the ongoing farming systems research at the ICRISAT Center, its cooperative programs, and its strategy for strengthening national research systems. It is well recognized that farming systems are location specific, therefore an international center can act only as a catalyst, pace setter, and concept builder. It has to work with national programs to develop and transfer appropriate technology and research to its target group of farmers and its client group of scientists.

RESEARCH PROGRAMS AT ICRISAT

ICRISAT has six main research programs -- sorghum, millets, pulses, groundnut, farming systems and economics -- and seven support programs including training. The research programs have interdisciplinary teams of scientists who work together to achieve the common goal -- improved and stable food production in the SAT. The research at ICRISAT Center is conducted keeping in mind the overall constraints of water and capital. To develop technologies relevant to the small farmers of SAT, special attention is paid to :

- Conducting research in low fertility areas that are comparable to the farmers' situation for testing crops with relatively little fertilizer inputs.
- The breeding material is evaluated in pesticide free area under natural conditions, without an umbrella of pesticides.
- The farming systems research is conducted largely under natural topographic conditions, in small watersheds, using labor intensive methods and animal drawn machinery. All new and perspective technologies are tested under natural environments at research center, and are evaluated for their performance under on-farm conditions in cooperation with the national research centers and village level studies.

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RESEARCH OVERVIEW: FARMING SYSTEMS

The main goal of farming systems research is to develop concepts and techniques for increasing production through better use of natural and human resources in the seasonally dry semi-arid tropics. These areas are characterized by harsh climate, erratic rains, and impoverished soils; they are inhabited by some of the world's poorest farmers, with meager resources for innovative and efficient agriculture. Rainfed and subsistence farming, intercropping, low intensity of cropping, use of human muscle and animal power are common features of agriculture of the areas. Keeping this background in mind, ICRISAT's Farming Systems Program has over the past seven years developed:

- Technology for double cropping of deep Vertisols, 20 million hectares of which normally are single cropped in SAT India.

- Efficient intercropping which improved production 20 to 70 percent over sole cropping; millet/groundnut on an average recorded 25 to 30 percent advantage.

- A small watershed concept for land and water management and increased crop production with a broadbed-and-furrow system and the Tropicultor or wheeled bullock tool carrier serving as king pins of the technology.

- A technique of harvesting, storing, and reusing runoff water for life-saving irrigation, extending the cropping season, or increasing the intensity of cropping. It is a concept of using rainwater in situ against the concept of irrigated farming based on transported water or mined water.

- A concept and technique of combining various steps in technology for a synergistic effect on increasing production in both Alfisols and Vertisols.

Farming systems research is integrating all aspects of research in a holistic way and studying the possibility of its transferability under farmers' conditions. With this objective in view, operational scale trials on cultivars fields have been startedin three villages -- Shirapur (Sholapur), Kanzara (Akola), and Aurupalle (Mahbubnagar) in the states of Maharashtra and Andhra Pradesh, India. This work is being done in cooperation with the national and the state research organizations.

The farming systems research is also being extended to West Africa, and it is interacting with national and regional programs in South America and Southeast Asia. We feel that in the future farming systems research will advance more in the direction of the 'on-farm' type trials and enter into this phase with the help of national programs and the cooperating farmers acting together to bring a revolutionary change in agriculture of the SAT.

COMPONENTS OF IMPROVED TECHNOLOGY

Past approches to resource development to increase agricultural production in the semi-arid tropics have achieved only limited success because they have not recognized the basic climatological and soil characteristics of the region nor utilized natural watershed and drainage systems (1). Better technologies are now being developed to ameliorate the effects of drought, increase food production per unit of land and capital, assure stability, and contribute directly to improving the quality of life.

WATERSHED MANAGEMENT

In rainfed agriculture the main source of available water is rain, but many of the soils of the region have poor infiltration characteristics and excess runoff and erosion or water logging can be serious problems at various times during the rainy season. The solution lies in developing technologies that make use of the natural topography and drainage patterns. The small watershed is a natural framework for resource development aimed simultaneously at stabilizing and incrasing crop production through more effective use of available water and at resource conservation through in situ conservation measures.

At ICRISAT over the last eight years and in operational-scale village-level studies over the last three years, a technology for land and water management on deep Vertisols using graded broadbeds and furrows within small watershed units has proved successful in reaching both the above objectives(2).

The 150 cm wide beds are graded across the contour to a 0.6 % slope and are separated by furrows that drain into grassed waterways. The broadbeds are not likely to be breached in heavy rainfall, and allow a flexible planting pattern in rows spaced at 30 cm, 45 cm, 75 cm, or 150 cm. They reduce runoff under both fallow and cropped conditions and greatly reduce soil erosion in comparison to ungraded fallow soils(3). The use of graded broadbeds and furrows gives higher gross returns and profits. They can be established successfully within existing field boundaries at some loss in profits.

Dry seeding of the crop about two weeks before the onset of the rains is possible on these soils if the early rainfall is fairly reliable (4) and in most years will enable a postrainy season crop to be taken thereby increasing greatly the gross returns, profits and the rainfall use efficiency.

SUPPLEMENTARY 'LIFE-SAVING' IRRIGATION

Dry periods within the monsoon are typical of many semi-arid tropical regions even when normal or above normal seasonal rainfall occurs. The result is usually a reduction in crop yield, especially on soils which have relatively low water holding capacities. The availability of water for supplemental irrigation is an important means to reduce risk and improve production.

During the 1974 rainy season at ICRISAT Center, most of the runoff storage reservoirs were partially (50-70 %) filled during the early part of the rainy season, thus providing water, it required, for 'life saving' irrigation during drought. The results of supplemental irrigation to crops on Alfisols during a 30-day drought in late August and early September were **spectacular.** Yields of sorghum and maize were approximately doubled by the application of one 5 cm irrigation. At product prices prevailing at the time of harvest, gross values of the increase due to the use of 5 cm of water were 3, 120 ; 2, 780 ; 1, 085 and 650 Rs/ha for maize, sorghum, pearl millet and sunflower respectively (5).

During the postrainy season, supplemental irrigation can substantially boost crop yields because residual soil moisture is usually insufficient to prevent some drought stress at important physiological stages of growth. Sivakumar et al (6) showed that supplemental irrigations given at the time of panicle emergence and flowering of grain sorghum grown on a deep Vertisol gave an additional yield of 3,560 kg/ha over the control treatment (2430 kg/ha). The net benefit accruing from the supplemental irrigations was Rs. 2,500/ha.

IMPROVED SOIL MANAGEMENT PRACTICES

Effective soil management practices in the rainfed semi-arid tropics must produce a suitable seed bed, ensure the proper placement of seed and fertilizer, destroy weeds, conserve soil moisture and minimise runoff and erosion.

Dry season primary tillage is now a common practice on the Vertisols of semi-arid India. The soils are ploughed in March or early April after the postrainy season crop is harvested. Because there is still some moisture in the soil, the power required for tillage is less than it would be later in the dry season, and the draft animals are well-fed and strong. Some weeds do grow, but these are removed in the final preparation of the seed bed which is done nearer to the onset of the rains. Pre-monsoon showers, which are nearly certain climatic events, soften the soil for the final land preparation.

Crust formation on the surface is a problem with many sandy textured soils in the semi-arid tropics. The power required to break the crust is low for most of these soils (see, however, Nicou and Charreau (7)) but the crust reforms after the rains and impedes seedling emergence. Incorporating organic matter into the soil helps to decrease the strength of the crust - probably by increasing soil moisture near the surface - but no satisfactory technology exists so far for dealing permanently with this problem.

Time of planting is important. Planting as early as the rains will permit will generally ensure good yields in most years, but research shows clearly that highest yields are obtained if planting occurs about two weeks late. Probabilities based on climatological evidence can now be used to predict optimum planting dates.

Accurate placement of seed and fertilizers ensures high seedling densities, vigorous early growth and resistance to drought, but is seldom attained in traditional agriculture. Practicable and economic new technologies to ensure accurate placement in rainfed semi-arid tropical agriculture have yet to be developed. It is probably the area where greatest gains can be made from increased research efforts.

Timely weed control measures are important to conserve moisture and to avoid completion to the standing crop. Poor weed control can reduce yields by 50 % or more. The use of herbicides is uneconomic or uncommon except on some cash crops, and weeding is done manually or by using animal drawn elements. Weeding is a major source of employment for landless labor in India, and a major bottleneck to increased production in labor-scarce areas of Africa.

Since the amount of water infiltrating into the soil is a function of the infiltration opportunity time and soil surface conditions, vegetative cover and land slope can be suitably modified to retain most of the rainfall on the ground surface. Reduced tillage maintains crop residues on the surface and contributes to improved infiltration and reduced evaporation and erosion. Land shaping in various forms has similar effects.

USE OF FERTILIZERS

Most of the soils of the semi-arid tropics are of low fertility, being almost universally deficient in nitrogen and phosphorus (8, 9). Sulphur deficiency is common in Africa where the annual rainfall exceed 600 mm.

Fertilizers are not commonly used in rainfed agriculture. Unirrigated districts in semi-arid India use an average of 18 kg/ha of fertilizers (N + P_2O_5 + K_2O) per hectare of cropped area compared to 57 kg/ha in irrigated districts (10). Most of the fertilizer used in the unirrigated areas is used on cash crops such as cotton, tobacco and groundnut.

There is much evidence to show that fertilizer use is economic on the staple semi-arid cereals. Seven hundred experiments on cultivators' fields with sorghum, maize and pearl millet in semi-arid India have given average grain of 14 kg of grains per kg of N and 7 kg of grain per kg of P_2O_5. Benefit to cost ratios are 4 or greater (11).

Soil type and particularly water-holding capacity have significant effects on the efficiency of fertilizer use (fig. 1). Crops grown on the same soil in the rainy season will usually have higher fertilizer use efficiencies than crops grown in the dry season on receding stored moisture.

Good plant nutrition stimulates early plant growth and root proliferation into the subsoil.The fertilized crop is able to draw effectively on subsoil resources of water and is better protected against drought (12).

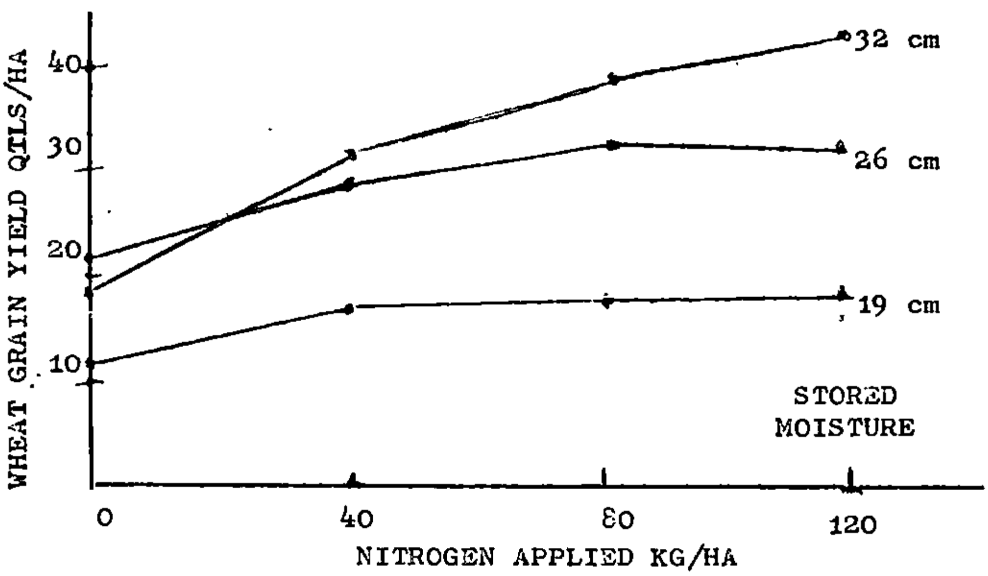

Fig. 1 : Response of rainfed wheat to nitrogen on soils having different stored moisture (Data of Meelu, O. P. et al. Fertilizer News 1976, 21 (9), 34-38).

USE OF IMPROVED AND APPROPRIATE SEEDS

The combination of genes that reduced plant height and susceptibility to lodging with genes for responsiveness to added nutrients resulted in quantum jumps in the yields of wheat and rice in irrigated agriculture. Similar approaches are proving successful with maize, sorghum, pearl millet and the grain legumes grown in rainfed conditions. Improved varieties and hybrids significantly outyielded local varieties. Hybrids that have satisfactory grain quality and levels of disease resistance combined with high yields are attractive to farmers. Although year to year variability in yield is higher for hybrids than for local varieties, the yield gains and other characteristics of good hybrids are sufficient to persuade farmers to take the higher risks involved. In Maharashtra State hybrids now make up 35 % of all sorghum planted, and more than 70 % in the postrainy season. Average yields in the state are 50 % higher than they were ten years ago.

The best crops to use in any particular district depend upon climate, soils and agricultural and socioeconomic traditions. Considerable efforts by the All India Coordinated Research Project for Dryland Agriculture have now determined the most appropriate crops for most of the semi-arid regions of India. For example, Randhawa and Venkateswarlu (13) give tables for most suitable crops and cultivars, for six districts with growing seasons usually less than 20 weeks, seven districts with growing seasons between 20 and 30 weeks and eight districts with growing seasons exceeding 30 weeks. The crop combinations recommended are the results of 3 to 7 years research work.

INTERCROPPING

Farmers in the semi-arid tropics commonly intercrop their land. There is considerable scope for improving the usefulness and productivity of intercropping as can be illustrated by considering two contrasting intercropping systems, sorghum/pigeonpea and millet/groundnut. The first is typical of those systems in which an early cereal (maize, sorghum or pearl millet) is combined with a slow-growing, reasonably tall long-season crop (pigeonpea, cotton, castor or cassava). The second is representative of systems using a tall cereal combined with a quick-growing low legume (beans, soybean, groundnut or cowpea).

<u>Sorghum/pigeonpea</u> : Pigeonpea is a long season crop that matures in 6 months but its early establishment is characterized by prolonged slow growth for as long as 2 months. During this period the crop is inefficient in utilizing resources, e.g. the sole crop during this period intercepts just 50 % of available light and produces only 20 % its total dry matter. Intercropping with earlier maturing crops such as sorghum improves the use of natural resources for the total crop period. This combination is very important in India. It shows promise in similar environments in West Africa. Its value as a hedge against disaster has already been mentioned.

<u>Millet/Groundnut</u> : This combination is adapted to soils with moderate water-holding capacities. Both crops mature less than 3 weeks apart, so the intercropping advantage cannot be as great as for sorghum/pigeonpea. Because the legume is usually an important cash crop, there may be no particular preference attached to either crop by the farmer. In such circumstances, optimal use of resources can be sought. The optimum row arrangement appears to be 1 millet : 3 groundnut with the same within row population as in the respective sole crops (14). This system gives a proportinate yield of 50 % of pearl millet and 77 % of groundnut giving a 27 % yield advantage over sole croping (Table 2). The increase comes mainly from the pearl millet which compensates for the low density by increased yield per plant.

Table 1. Grain yields and land equivalent ratios in sorghum/pigeonpea intercropping on two soil types (Average of 3 years).

	Vertisols					Alfisols				
	Yield		Land equivalent			Yield		Land equivalent		
	Sole	Inter-crop	LES*	LEPP**	Total	Sole	Inter-crop	LES*	LEPP**	Total
Sole crops										
Sorghum	4500		1.00	-	1.00	4573	-	1.0	-	1.00
Pigeonpea	-	1314	-	1.00	1.00	-	1773	-	1.0	1.00
Intercropping										
1 : 2 Sorghum/ Pigeonpea	4240	945	0.94	0.72	1.66	3641	1140	0.80	0.64	1.44

*LES (Land equivalent ratio for Sorghum) is the relative land area required by a sole crop of sorghum to achieve the yields produced by the same component in the intercrop.

**LEPP (Land equivalent ratio for Pigeonpea) is the relative land area required by a sole crop of pigeonpea to achieve the yields produced by the same component in the intercrop.

Table 2: Grain or pod yields and land equivalent ratios in pearl millet/groundnut intercropping (Average of 3 years).

	Yields (kg/ha)		Land equivalents		
	Millet	Groundnut	LEM*	LEG**	Total
Sole crops					
Pearl millet	2370	-	1.0	-	1.00
Groundnut	-	2332	-	1.0	1.00
Intercropping					
1:3 millet/G'nut	1177	1796	0.50	0.77	1.27

*LEM (Land equivalent ratio for millet) is the relative land area required by a sole crop of millet to achieve the yields produced by the same component in the intercrop.

**LEG (Land equivalent ratio for groundnut) is the relative land area required by a sole crop of groundnut to achieve the yields produced by the same component in the intercrop.

The advantages obtained in the above combinations are the result of the complementary use of resources over time and space without additional cost. The advantage of intercropping, in fact, tends to be higher at low fertility or in low moisture conditions; but this does not mean that this practice is valid only in poor situations. Although the relative advantage over sole cropping decreases with higher fertility, the absolute advantage in total crop yields increased (15).

OTHER CROPPING SYSTEMS

Many of the Vertisols in India are cropped in the postrainy season after a rainy season fallow. ICRISAT research has shown that some of these can be cropped during the rainy season without affecting the postrainy season crop resulting in substantial increases in yields and profits. The rainy season crop must be planted early in dry soils before the onset of the rains, which also avoids the problem of working in wet, sticky soils. Postrainy season crops can be established either sequentially (e.g, chickpea or safflower), or - with some difficulty - by relay planting (e.g. sorghum and pigeonpea). Intercropping of sorghum/chickpea or safflower/chickpea in the postrainy season had been examined but the intercropping advantage is only about 20 %. Double cropping is less profitable than intercropping. For example, intercropped maize/pigeonpea is 73 % more profitable and 34 % less variable than maize followed by chickpea. The problems with double crop are additional cost involved in establishing the second crop and the poor crop stands that may sometimes result due to the early cessation of rains.

On soils such as Alfisols, since planting of a second crop is not possible after a full season cereal, efforts have been made to extend the cropping season through the use of intercropping or relay planting or by shortening the cereal growing season by transplanting seedlings. Some promising cropping systems have been identified (Table 3). Combinations involving castor, an industrial crop, gave maximum net returns, but for food crops the extended cropping systems gave higher net returns than sole crops.

Table 3: Extended cropping on Alfisols, 1978-79

Systems	Yields (kg/ha)		Total	Net
	Crop 1	Crop 2	gross value Rs/ha	returns Rs/ha
Pearl millet + Horse gram (sequential)	1940	616	2168	1079
Mungbean + Castor (relay)	634	885	2772	1514
Castor (sole crop)	1462	-	2485	1630
Sorghum + Sorghum (ratooning)	2516	505	2417	1322
Sorghum/Pigeonpea (intercropping)	2169	417	2694	1584
Pearl millet/groundnut + Safflower Intercrop	849	208	2347	1119
Sole Millet	1940	-		753
Sole Sorghum	2506	-		1118

Value for 100 kg pearl millet Rs. 80, Mung Rs. 200, Sorghum Rs. 80, Pigeonpea Rs. 230, Groundnut Rs.150, Safflower 175, Horsegram Rs. 100 and Castor Rs.179. Costs of seeds, fertilizers, operations, insecticides and initial land preparation are deducted for the estimation of net returns.

Proportionate cropping, i.e. allocating land resources to crops based on formulae relating crop durations to the probabilities of adequate soil moisture can help decrease the risk of loss and increase overall farm productivity. Research conducted at Haryana Agricultural University in northern India showed that allocation of 40 % of the land to guar, a very drought resistant crop, with a 120 day growing season, 40 % to pearl millet, a drought resistant crop, with a 70 day growing season and 20 % of land to mung bean with a 50 day growing season allows the farmer to harvest all the three crops in the best years and at least two crops in all but severe drought years.

Crop rotations are used particularly in semi-arid West Africa to increase production. In low intensity cropping, the cropping sequences include fallow. Charreau (16) recommends one year of fallow or green manure plowed under followed by groundnut by cereal and finally by groundnut or cowpea. The cereal is usually long deason pearl millet or sorghum. The effects on soil physical properties of incorporating green manure are well known resulting in beneficial effects on rooting and production of the succeeding crop. Where rainfall is fairly low and irregular as in northern and central Senegal, a four year rotation of fallow or pearl millet as a green manure followed by groundnut followed by cereal followed by groundnut is recommended or a five year rotation such as fallow or green manure - pearl millet - groundnut - pearl millet - groundnut.

In intensive cropping, the fallow period is eliminated and plowed under grass fallow or green manure is replaced by plowed under straw of short-season cereals (17).

ICRISAT'S COOPERATIVE PROGRAMS

A basic premise in the establishment of ICRISAT was that the institute would serve to strengthen and support national research programs on production of the five ICRISAT crops, both in the host country and in other SAT nations. The major objective is to generate improved genotypes and technology to increase major objective is to generate improved genotypes and technology to increase and stabilize food production. The form of assistance and cooperation may differ considerably, depending on each country's specific requirements, but at all times the assistance must be supportive and not duplicate or compete with the national programs. It is essential to work in close harmony with national programs and with other agencies having mutual concerns and interests.

According to the climatic definition of the semi-arid tropics, most of the area (66 %) is in Africa. The SAT regions form a wide belt below the Sahara desert, extending the width of the continent and south through East Africa to include large areas of southern Africa. In Asia the SAT cover much of India, northeastern Thailand, and other smaller areas. Other SAT regions of the world include large sections of Mexico, Central America, northeastern Brazil, Paraguay, and northern Autralia.

STRATEGY FOR STRENGHTHENING NATIONAL RESEARCH SYSTEMS

An objective of all international centers and agencies working within a country or region is to strengthen national research systems. Obviously, there is no simple single answer to the question of how this can be most effectively achieved. The countries with which an international center cooperates vary considerably in scientific expertise and infrastructure development; each country has its own particular combination of strengths and weaknesses that sets it apart from its neighbors.

Perhaps the ideal working relationships between international and national research programs with an effective two-way transfer system is being approached by ICRISAT and its host government, India. From the earliest stages, ICRISAT has enjoyed the counsel and advice of senior members of the Indian Council of Agricultural Research (ICAR) and--under formal working agreements with ICAR--continuing collaboration with the All India Coordinated Programs and the Indian Agricultural Universities. Admittedly, India has a scientific resource base and sophisticated research and extension service not equalled in many countries, but we feel that much of the Indian experience can be applied elsewhere.

ICRISAT, like many international centers, has the capability of assisting national program in four main areas:

1. Provision and exchange of germplasm. There is universal interest in strengthening national breeding programs; consequently, ICRISAT routinely supplies source material and various nurseries for screening, testing, and hybridizing to more than 40 cooperating countries. In return, ICRISAT has access to the indigeneous genotypes within national programs, and has built up a broad-based genetic resource for further refinement and distribution.

2. Assistance in training. ICRISAT considers training to be among its most important activities; the eventual goal is to make the research capability of cooperating countries self-sufficient. Various forms of training, designed to fit the particular needs of each country, are offered.

3. Promotion of scientific interaction. A third activity useful to all cooperating national systems is the convening of workshops, seminars, and conferences to promote scientific interaction and communication. Participants can also visit research programs and facilities at other institutions simultaneously. So far, ICRISAT has organized ten international workshops in various research areas.

4. Provision of technical assistance. The fourth area where international centers can strengthen linkages with national programs is in providing technical assistance. The most appropriate form, whether short-term consultancy or long-term assignment, depends on the indigeneous scientific strength and the actual organization of human resources within the host country. Although ICRISAT has only four years of experience in this type of cooperative activity, response from countries where scientists have been posted is encouraging.

ROLE OF ICRISAT SCIENTISTS IN COOPERATING COUNTRIES

Agreements between ICRISAT and the host countries vary by country. Generally, the program of each ICRISAT scientist posted in a cooperating country has three components:

i. A direct contribution to the national program.

ii. A contribution to the regional program, consisting mainly of the the organization and supervision of regional trials and consultancy visits to neighboring countries.

iii. A contribution to the international program in supervision of trials or nurseries to provide ICRISAT Center with information on the behavior and performance of different genotypes in various ecological situations. An important function is to provide germplasm from cooperating countries for inclusion in the germplasm collection and the breeding programs at ICRISAT Center.

The demarcation between these three components is not always clear and may sometimes appear to be somewhat arbitrary. However, in each situation, an attempt has been made to establish this tripatrite role so that the relationship between ICRISAT scientists and their colleagues in the national programs can be defined and close working links can be forged. The relative importance of the three components may vary considerably both between countries and between scientific disciplines. As far as possible, ICRISAT scientists are integrated into the local research centers and are expected to follow the general working regulations of those centers; however, ICRISAT scientists have full control of the allocated funds, thereby maintaining the degree of autonomy necessary to effectively carry out their assignments.

On the whole, these arrangements with the national research services have proved satisfactory both scientifically and administratively. By such close association with national research, the ICRISAT scientists become fully aware of the research problems in host countries of the progress of national research services, and of the various constraints on host country and extension. The scientists are thus in the best position to reappraise their programs regularly to make them more meaningful. They have an important role in providing practical training to local technicians, and, in some cases, scientists on the staff; they also often identify candidates for training at ICRISAT. The exchange of both scientific information and seed material between ICRISAT and the national research services is very free under these conditions. It is, in fact, a true cooperation, in the full sense of the word, in that there is reciprocal benefit for both parties.

Two main principles are followed regarding the transfer of new technology and improved germplasm to cooperating countries.

- This transfer is made only through the national research institution, never directly to extension or development agencies.

- The transfer is not encumbered by any requirement of special references to ICRISAT. With improved germplasm, particularly, the local research institutions are free to choose any ICRISAT material for release to farmers and to label it as they wish.

CONCLUDING REMARKS

ICRISAT is concerned with developing agricultural technologies and alternative strategies for the seasonally dry semi-arid tropical regions for stabilizing and increasing crop production. Our work will be meaningful only when the results can be effectively conveyed to their ultimate user - the farmer - through the scientists and extension agencies. Our research areas include crop improvement, in which the technologies developed have low site-factor constraints, and farming systems, in which the technologies have high site-factor constraints. Transfer of technology through seed is more or less direct through there are difficulties that cannot be overlooked, but transfer of farming systems technologies with high site-factor constraints is much more difficult.

Regardless of the methods used for transfering technology, and regardless of the magnitude of site-factor constraints, new agricultural technologies must be subjected to on-site testing, this indicates the need to build up the indigeneous agricultural research capacity for adaptive research that was required. A small national research effort on a particular commodity will screen and transfer only relatively simple technology with low site-factor constraints. A large, mature national research effort will have many more options. It will be more capable of transfering technology with high site-factor constraints but will tend to be most interested in transfering principles and methods and advanced scientific knowledge.

The transfer of technology through adaptive research is also not sufficient. Social science research repeatedly confirms the need for new technologies. In the West African semi-arid tropics, for example, thereis need forimproved varieties of sorghum and millet, new farming systems. Many of the principles of these technologies may exist, but the technologies do not. Much research must be done, mostly by the national agricultural research institutions. ICRISAT and other external research institutions can only help.

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