APPENDIX 4 : Estimated farm-gate prices of inputs for and outputs from five tree species suitable for dryland cultivation.

Description	Unit	Price (Rs) Financial	Price (Rs) Economic[1]
	Inputs		
Grass seed	Tonne	500	500
Labour	100 Man days	500	400
Seedlings	100 no.	25	25
	Outputs		
Air dried grasses	Tonne	100	150
Loppings from			
i) Acacia tortilis	Tonne	100	150
ii) Albizzia lebbeck	"	100	150
iii) Prosopis cineraria	"	600	900
iv) Zizyphus sp.	"	300	450
Green Pods from			
i) Prosopis cineraria	"	1000	1000
ii) Prosopis juliflora	"	500	500
Dry seed from			
i) Acacia tortilis	"	6000	6000
ii) Albizzia lebbeck	"	6000	6000
iii) Prosopis cineraria	"	2000	2000
Ber Fruit	"	500	625
Poles from Albizzia Lebbeck	100 no.	1000	1250
Small timber from prosopis cineraria	100 c ft	60	75
Fuelwood	Tonne	180	225

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DRY FARMING RESEARCH : ISSUES AND APPROACHES*

N.S. Jodha**

Abstract

The major problems constraining generation of dry-farming technology are weather variability, and low resource allocation for research. Scientists find research on drylands unattractive as they are often, by training and incentive systems, accustomed to experimentation in stable agro-climatic environments.

This paper discusses the implications of these constraints in terms of the research policy-makers' expectation profile, recognition of location specificity, developing of multioption technology, and widening the research infrastructure. It also discusses past efforts in dryland research and some features of the present approach: (1) integration of resource and crop-centred technologies; (2) multilocational testing; (3) mechanisms for farm-level testing; and (4) problem-focused research.

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The study identifies some unattended issues: (a)inadequate analysis of the physical environment; (b)indifference to farmer circumstances; and (c)a strong bias towards crop production; it argues that these issues are deserving of attention, if technologies are to be evolved to suit different dryland farming situations.

Introduction

The agro-climatic constraints that operate at the farm level also influence the whole process of technology development for dry farming. The weather-induced instability of dry farming is held to be the primary cause for official indifference and hence poor resource allocation to dry-farming research. This paper deals with some basic problems constraining the generation of dry-farming technology. For evolving an appropriate strategy for dry-farming research we require a better understanding of the implications of agro-climatic instability for development and transfer of technology. The paper comments briefly on past and current research efforts in the field, to highlight the extent to which the research strategy incorporates the imperatives of agro-climatic constraints.

In order to put the following discussion on research-related issues in proper perspective, it will be helpful to briefly indicate the position of dryland farming in the overall context of Indian agriculture. According to table 1, the dry-farming areas–arid and semi-arid tropical zones (with <500-1500 mm annual rainfall and little or low irrigation)–account for 43% of the total geographical area of India. About 31% of India's rural population lives in these regions. These regions account for 48% of gross cropped area and 26% of gross irrigated area in India. They account for substantial area (60 to 80%) of coarse cereals, major pulses, oilseeds, and fibre crops. These figures would increase further if the low rainfall regions having higher irrigation (>25% of gross cropped area) but substantial acreage (>25% of gross cropped area) under rainfed dry crops were to be included in the dry-farming regions.

Details under Table 1 (based on Mitra and Mukherji, 1980) also indicate that low productivity and stagnation characterise most of the dry-farming districts. Accordingly, 98% of lowest productivity (>Rs 600/ha) districts in India (excluding union territories) belong to the

TABLE 1 :Details indicating position of dry-farming areas in Indian agriculture[1].

Share of dry farming areas in India's:	(%)	Proportion of dry farming districts in the total (281) districts characterised by[2]:	(%)
- Geographical area	42.8	—productivity level (Rs/ha)[3] —	
- Rural population	30.7	. Rs. 1600 and above (41)	2.4
- Gross cropped area	48.1	. Rs. 1200-1600 (42)	14.3
- Gross irrigated area	25.8	. Rs. 600-1200 (140)	43.3
- Area of coarse cereals[4]	80.0	. Rs. < 600 (58)	98.2
- Area of pulses[4]	59.1	—Agricultural growth rates[4] —	
- Area of edible oilseeds[4]	60.1	. 8 to 10% and above (7)	28.6
		. 4 to 8% (48)	36.1
- Area of fibre crops[4]	72.7	. <1 to 4% (156)	43.0
		. (-) <1 to 4% (50)	40.0
		(-) 4 to 8% and below (20)	85.7

dry-farming zones. Similarly 43% of the districts with productivity level of Rs 600-1200/ha belong to the dry zones.

Even in terms of agricultural growth performance, dry-farming zones are in no way better. Dry zone districts account for 85% of the districts in India that had negative annual growth rate ranging between 4 to 8% and more during 1962-1965 to 1970-1973 (Mitra and Mukherji, 1980). About 40% of the districts with a negative growth rate (upto 4%) belong to the dry-farming zones. These details present a rather dismal picture of dry-farming areas. But they also reinforce the need for greater attention to these areas, including a thorough development of improved technologies to facilitate growth of dryland agriculture.

1. Table adapted from Jodha (1984); includes all arid and semi arid tropical districts (annual rainfall, <500 mm-1500 mm; irrigation, 0-25% of gross cropped area). In many of the districts irrigation does not exceed 10% of gross cropped area. If districts with irrigation exceeding 25% of gross cropped area but still dominated by dry crops are included in the dry farming areas, the figures in this table will increase substantially.
2. Details based on Mitra and Mukherji (1980). Figures in parentheses indicate number of districts in India (excluding union territories).
3. Agricultural productivity calculated on the basis of production and prices of 9 major crops during 1972-73.
4. Crops covered: coarse cereals include sorghum and pearl millet; pulses include pigeonpea (tur) and chickpea (Bengal gram); oilseeds include groundnut; among fibre crops, only cotton is included.
5. Growth rates during 1962-65 to 1970-73.

Weather Variability as a Key Constraint

The key problem with dry farming areas is unstable crop production as a result of a large degree of heterogeneity in terms of soils, quantity and distribution of rainfall, and other natural endowments relevant to agriculture. The prime factors in this unstable production are high variability of agro-climatic factors, particularly spatial and temporal variability of rainfall. Instability affects every farm-related

ecision in these areas, be it the farmer's choice of crop or public policies guiding investment in these areas. This tends to reduce the traditional farming system to a survival mechanism rather than a growth-oriented activity, and perverts public programmes into externally supported protection measures against instability, instead of development strategies based on local potential. There is one difference, however, between the attitudes of farmers and the concerns of policy-makers: while the farmer is constantly busy negotiating the problem of low and unstable production through a variety of adjustment mechanisms (Jodha, 1978), policy-makers remain generally indifferent, only to awaken to the situation when the problem gets aggravated during serious droughts and famines (Jodha, 1979).

An important aspect of the hasty official response to instability of dry-farming areas is that it tends to seek solutions which are often heavily dependent on resources imported from other areas. Such solutions range from water for protective irrigation as a long-term protection measure (Jodha, 1979) to relief supplies imported as an ad hoc measure to help drought-hit areas (Jodha, 1975). This has several adverse, interrelated consequences. It tends to (1) perpetuate the dependence of dry-farming areas on external resources, which are always limited; (2) project dry-farming areas as a permanent liability to the rest of the economy; (3) constantly disregard options suited to make use of local potential; and (4) cause policy-makers to assign a low priority to resource allocation for identification and harnessing of local potential.

The last consequence is a central problem in technology development for dry-farming. When limitations rather than the potentials of dry-farming areas shape the judgement of policy-makers, and where constant transfer of external resources is considered as the only means to help them out from crises, adequate attention and resource allocation to a long-gestation activity like development of dry-farming technology is difficult. Besides its low attractiveness within the public-resource supported activities, dry-farming research suffers from poor competitiveness for resources when compared to well-endowed agricultural areas. Relatively limited chances for technological breakthroughs are perceived in dry-farming areas. Because of the predominance of low value crops in these areas, a lower potential payoff to research investment is expected. Dry-farming research thus becomes a low-priority activity. It is in this context that weather-induced instability is considered as a primary cause for lower resource allocation to dry-farming research.

Low Research Resource Allocation: Some Evidence

Data are inadequate to clearly indicate resource allocation to research in comparison to development or protection programmes in dry-farming areas. Financial allocation to agricultural research often does not provide a break-up by crops and agro-climatic zones. It is a hard task to decipher stated and implicit priorities in agricultural research. In this paper, we attempt to measure research-resource allocation to dry-farming versus other agricultural research, with the help of various indicators. The indicators include the total number of field experiments, number of scientists deployed, infrastructural facilities for research, etc., on dry-farming research vis-a-vis research on other crops and areas. Tables 2,3, and 4 furnish the relevant information.

According to Table 2, of the total agricultural field experiments conducted in India during 1948-1959, the share of any individual main crop of dry-farming areas (sorghum, pearl millet, pulses, oilseeds) did not exceed 4.2%. The share of crops like rice, wheat, sugarcane, cotton, and vegetables and fruits in total experiments was much higher and ranged from 7 to 42%. Furthermore, their share in total experiments was disproportionately higher than their share in gross cropped area of the country; the reverse was the case for the main crops of the dry-farming regions. In most cases, the share of dry crops in the gross value of agricultural produce in the country during the reference period was also higher than their share in research investment. Thus research investment on dry crops was not in keeping with their importance in the country, considering their extent and production.

If data from the experiments under All-India Coordinated Agronomic Research Project (AICARP) are any indication, the situation had not changed even after 15 years. Sorghum and pearl millet continued to get a lower priority in total agricultural experiments than would be justified by the total value of their output (see Table 2). Another feature revealed by these data is that 76.7% of the

TABLE 2: Distribution by crop of agricultural field experiments, coordinated agronomic experiments, and ad hoc research schemes funded out o agricultural produce cess in India during different periods.

Crops	Share of different crops (%) Field experiments 1948-1959[1]	Ad-hoc research schemes 1929-1977[2]	Coordinated agronomic trials 1976-77[3]	Gross cropped area[4] 1951-1958 (average)	1975-1977 (average)
Rice	42.2	16.9	40.8	21.7 (39.5)[5]	23.1 (33.1)
Wheat	14.5	9.0	45.5	7.7 (10.8)	12.2 (14.2)
Sorghum	4.2	0.6	4.1	11.7 (6.5)	9.4 (5.0)
Pearl millet	1.5	0.3	4.4	7.5 (3.3)	6.6 (2.1)
Pulses	3.9	6.1	-	14.9 (11.7)	13.8 (8.2)
Groundnut	3.0	3.3	-	3.7 (6.7)	4.2 (5.1)
Other oilseeds	1.4	3.5	-	4.6 -	4.9 (0.5)
Mixed crops	2.5	-	-	-	-
Cotton	7.2	11.2	-	4.9 (8.8)	4.2 (4.3)
Sugarcane	12.6	9.8	-	1.2 (10.7)	1.7 (9.2)
Tobacco	3.5	2.1	-	0.3 (2.0)	0.3 (0.9)
Vegetable/fruits	10.2	30.1	-	-	-
Other crops	11.3	6.2	5.2	20.8 -	19.6 (6.3)
Dry farming	-	1.2	-	-	-
Total	100.0	100.0	100.0	100.0	100.0
(Absolute numbers)	(17755)	(624)	(1931)		

1 Source: Adapted from IARS 1962 and 1965
2 Source: Adapted from ICAR 1979 Research schemes with clear indication of the crops involved are considered.
3 Only cereal crops are covered.
4 Source: Adapted from DES, Indian Agriculture in Brief (different volumes)
5 Figures in parantheses indicate % share of each crop in gross value of their produce put together. Calculations, for concerned years are based on data from DES, Bulletin of Food Statistics and CSO, National Accounts Statistics.

TABLE 3 :Proportion of scientists deployed in Central Research Institutes dealing primarily with the problems of dryland areas and other areas in India[1].

	% Scientists deployed during				
	1929-1938	1939-1948	1949-1958	1959-1968	1969-1978
Institutes with primary focus on drylands[2]	0.0	0.0	5.1	16.4	18.9
Other institutes	100.0	100.0	94.9	83.6	81.1
Total (number)	100.0 (104)	100.0 (178)	100.0 (530)	100.0 (1186)	100.0 (3496)

1. The Table does not include details of scientists deployed by universities and various all-India coordinated research projects, as requisite data were not readily available. For some relevant details see Tables 4, 5, and the text.
2. Central Arid Zone Research Institute, Indian Grass Land and Fodder Research Institute, Central Sheep and Wool Research Institute, Central Soil and Water Conservation Research and Training Institute, and National Dairy Research Institute are included in the group.

Source: ICAR 1979.

agronomic trials were irrigated experiments that were of little relevance to dry-farming areas.

The lower priority to dry crops is also indicated by the meagre (0.3 to 3.1%) shares of these crops in the ad hoc research schemes supported by the Indian Council of Agricultural Research (ICAR) through agricultural produce cess funds from 1929 to 1977.

The pattern of research resource allocation to dry-farming indicated by Table 2 is further supported by other data sets. Table 3 presents the distribution of scientists deployed in central research institutes from 1929 to 1979. Up to 1948, no scientist was deployed at any central research institute to deal primarily with the problems of dry-farming areas. In the decade 1949-1958, they constituted 5.1% of the research manpower, though the total number of scientists deployed at all institutes increased more than 5-fold when compared to the decade 1929-1938. From 1949-1958 to 1969-1978 the number of scientists engaged in central institutes increased more than 7-fold. The increase in manpower involved in dryland-related research during this period was also very substantial though their relative share ranged between 16-19% during the period.

TABLE 4 :Distribution of agricultural research resource allocation for dry farming and other areas/crops[1].

	Share % of research institutes with primary focus on				
	Dry farming area/ crops	Rice, wheat, and wet areas	Cotton, jute, sugarcane and tobacco	Vegetables and fruits	Total
No. of research institutes/ stations[2]	15.2	42.5	22.9	19.4	100.0 (642)
No. of research workers	17.4	46.7	20.5	15.4	100.0 (4058)
Budget allocation (in '000 Rs)	18.1	50.9	20.3	10.7	100.0 (52270)
Crops' share in 1969-70					
Gross cropped area[3]	37.4	33.2	6.6	-	-
Value of output[4]	22.1	44.9	13.2	-	-

1. Data tabulated from Rajagopalan and Satyanarayana, 1969.
2. This excludes institutions engaged in teaching besides research (e.g., universities), institutions whose work is not specific to particular crop or agro-climatic conditions, and institutions doing research on livestock and forest.
3. Based on details from DES, Indian Agriculture in Brief, 1969-70.
4. Based on CSO, National Accounts Statistics, 1969-70.

Table 4 presents further details of resource allocation to research on dry crops and dry areas during 1969 – the latest year for which such data in usable form are readily available. Research institutes or stations (excluding those engaged in teaching and research, i.e., agricultural universities/colleges) with primary mandate for dry-farming areas and crops constituted about 15% of total agricultural research institutes in India. Their share in total research staff was about 17%, and in budget allocation about 18%. In comparison, the share of rice and wheat in wetland areas was 43% in total research institutes, 47% in research staff, and 51% in budget allocation. Even the share of cotton, sugarcane, and tobacco exceeded that of dry crops and dry areas by 2 to 8% in the allocation of these research resources. Viewed in the context of their contribution to cropped area, this further confirmed the disproportionately low resource allocation to dry-farming areas/crops.

A Positive Shift

There has been a considerable positive change in the situation regarding resource allocation to dryland research during the last decade. Programmes initiated largely during the early 1970s have gained momentum. Consequently, in the early 1980s, dry-farming research received more resources than it ever had. The All India Coordinated Research Project for Dryland Agriculture (AICRPDA), established in 1970 with 23 centres representing major agro-climatic zones, had by 1980-81 nearly 200 scientific and technical personnel working exclusively on the problems of dryland agriculture. The sixth five year plan (1980-85) provided for 468 professional staff and a budget of Rs 20 million for dryland research through AICRPDA.[1] The All India Coordinated Research Projects on sorghum, millets, pulses, and oilseeds (the crops largely grown in dry-farming areas), have been provided with nearly 1300 scientists and a budget of Rs 85 million during the sixth plan. This represents a three- to five-fold increase in the research resource allocation to these crops, when compared to the situation about 15 years ago (Mahapatra et al., 1984).

That increase in research resource allocation has resulted both from overall increase in agricultural research investment in the country and from greater attention to dry-farming areas and crops following widening regional inequalities induced by the green revolution in wetland areas. In the absence of data on resource allocation to wet crops and wet areas, it is difficult to precisely indicate the relative shift in emphasis to dry-farming.

A significant dimension to increased attention and resource allocation to dry-farming research is that it was initiated on a large scale by the international community. The Consultative Group on International Agricultural Research (CGIAR) established the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in 1972 with headquarters at Patancheru (near Hyderabad) in India. In 1982, ICRISAT had nearly 170 professional scientists and technical staff stationed in India. Its core operations budget was about $12.5 million. Since the geographical mandate of ICRISAT extends to nearly 50 countries in semi-arid tropical zones, research resource allocation through ICRISAT is not confined to

India alone. Even when the work is done in India its results are used by other semi-arid tropical areas. Hence, it is difficult to quantitatively indicate the research resource availability to Indian dry-farming areas through ICRISAT. More important dimension is the qualitative improvement in dryland research with the setting up of ICRISAT. The efforts of AICRPDA and ICRISAT are complementary and ultimately help development of dry-farming technology.

Professional Unattractiveness to Scientists

The dependence of crop output on the weather has a strong disincentive effect for scientists to engage in dry-farming research. This may continue even after the financial and material resource allocation to dry-farming research is enhanced, as it has happened since the early 1970s. Often, agricultural scientists–both by training and incentive system-are accustomed to experimentation in stable agro-climatic environments. This permits use of standardised methods, ensures stability of results, and increases the possibility of quick and assured rewards through experimentation under usually high-input conditions. The highly fluctuating agro-climatic conditions in dry-farming areas are not conducive to such experimentation. On the contrary, experimental results in a dry-farming environment suffer from temporal and spatial instability to the extent of shattering an average scientist's confidence in his results. In fact, until recently, many scientists engaged in dry-farming research did not do so by choice. There were instances where scientists were transferred to dry-farming research as a punishment.

Data from various experiments conducted at different centres during different years by AICRPDA may help illustrate the instability of experimental results. Tables 5 and 6 present results of experiments from some centres of AICRPDA. They were designed to identify crops that were efficient moisture users and performed well in drylands. Hybrid sorghum CSH 1 yields, according to Table 5, varied from 1.04 to 4.18 t/ha at Akola, 0.33 to 3.63 t/ha at Rajakot, and 0.29 to 2.16 t/ha at Udaipur during different years. Similar differences in yields were recorded during the same years across locations. Hybrid pearl millet (Table 6) too reflected a similar trend; at Jodhpur, its yield ranged from zero to 1.86 t/ha during different years; at Anantpur 0.01 to 0.83 t/ha; at Rajkot 0 to 2.21 t/ha;

TABLE 5 : Yields of sorghum from specific experiments at different locations in the dry-farming areas during different years.

Location; rainfall (mm) its variability (% C.V.); and soil type	Experimental yield (t/ha) in different years					Cultivar
	1971-72	1972-73	1973-74	1974-75	1975-76	
Akola (Maharashtra); 824; 27%; medium deep black soil.	1.04	1.93	1.98	2.52	4.18	CSH 1
Hyderabad (A.P.); 788; 27%; red loam soil.	N.A.	1.78	4.52	4.92	N.A.	CSH 1 & others
Indore (Madhya Pradesh); 987; 29%; deep black soil.	3.08	2.29	2.12	3.18	N.A.	CSH 1
Rajkot (Gujarat); 750; 76%; medium deep black soil.	1.98	0.33	0.63	0.0	3.63	CSH 1
Sholapur (Maharashtra); 704; 29%; deep black soil.	0.88	0.0	1.08	1.49	N.A.	M 35 1
Udaipur (Rajasthan); 685; 27%; medium deep black.	2.10	1.11	0.29	2.16	N.A.	CSH 1 & others

N.A. = Not available. Experimental results were often not reported when crops failed.

Source: Tabulated from results of experiment type SA-1, SA-2 or CS-1 from review reports of rainy season data of AICRPDA centres for different years.

TABLE 6 :Yields (t/ha) of pearl millet from specific experiments at different locations in dry-farming areas during different years.

Location (Annual rainfall (mm); C.V. (%); and soil type.	Experimental yield (t/ha) in different years					Cultivar
	1971-72	1972-73	1973-74	1974-75	1975-76	
Akola (Maharashtra); 824; 27%; medium deep black soil.	0.71	0.86	1.25	1.18	2.48	HB 3
Anantapur (A.P.); 577; 28%, red loam soil.	0.37	0.73	0.65	0.83	0.01	HB 3
Hissar (Haryana); 328; 39%; sandy soil.	1.57	0.26	0.84	0.26	3.53	HB 3
Hyderabad (A.P.); 788; 27%, red loam soil.	1.21	1.18	2.20	0.65	N.A.	HB 3 others
Jodhpur (Rajasthan); 380; 53%; red loam soil.	0.0	0.97	3.23	0.0	1.86	HB 3
Rajkot (Gujarat); 750; 76%; medium deep black soil	2.21	0.60	0.91	0.0	1.62	HB 3
Sholapur (Maharashtra); 704, 29%; deep black soil		0.0	3.12	2.06	2.48	HB 3

1. Results of experiment SA-1, SA-2, or CS-1 designed to assess efficiency and performance of different crops in utilising rainfall and stored moisture.

N.A. = Not available. Experimental results were not reported when crop failed.

Source: Tabulated from review reports of rainy season data of AICRPDA centres for different years.

at Hissar 0.26 to 3.53 t/ha; and at Sholapur 0 to 3.12 t/ha. Yield fluctuations across locations during the same periods were also equally significant.

Table 7 presents the yield rates of oilseed and pulse crops at selected centres during different years. In some cases, pulses were more stable than sorghum and pearl millet. By and large, the temporal and spatial instability of yields also affected oilseeds and pulses.

In contrast to the wide fluctuations in the experimental yields of crops reflected in Tables 5, 6, and 7, the yields of rice, wheat, or other crops experimented under assured water conditions were more stable. This may be indicated by some data from experiments (i.e., Experiment No. 1-a–production potential and economics of high intensity crop) conducted under the AICARP during 1978-79 to 1982-83. Of the selected major wheat-growing areas, the widest yield gap at one location between any two consecutive years during the period under review was 1.63 t/ha. This gap for rice was 1.28 t/ha. Furthermore, these yield gaps were from higher yields in the succeeding years and represented growth in yield levels rather than fluctuations in yields. Owing to the difference in experimental designs, the results obtained for wheat and rice may not be strictly comparable with the results obtained for dry crops, but they do indicate the impact of assured moisture on experimental results.

The disincentive effects of such instability, characterising the results of dry-farming research, for scientists and policy-makers are not difficult to imagine. Besides illustrating an important source of disincentive, our discussion also highlights the strong location and season specificity of research results. This feature of dry-farming activity–be it on the farmer's field or at research stations–will persist as long as agro-climatic variability continues to affect farming. Before one could tackle the problem emanating from basic constraints, its fuller implications should be understood.

Implications of Key Constraints

The task of developing technology for dry-farming areas forces policy-makers and scientists to deal with an inhospitable agro-

TABLE 7 : Experimental yields (t/ha) of oilseeds and pulse crops at different locations during different years.

	Experimental yield (t/ha) in different years					
Crop/location	1971-72	1972-73	1973-74	1974-75	1975-76	1976-77
Groundnut[1]						
Akola	0.52	1.49	1.50	1.38	1.20	N.A.
Anantapur	0.43	0.53	1.62	1.33	2.17	0.0
Indore	1.11	2.02	1.51	-	-	-
Jodhpur	0.0	0.41	3.00	0.0	-	-
Rajkot	0.47	0.75	0.54	1.27	3.51	0.84
Sholapur	-2	0.0	2.47	1.08	1.49	-
Sunflower						
Akola	1.11	1.62	0.71	0.87	1.43	-
Anantapur	0.75	-	-	0.46	0.91	0.0
Indore	1.37	0.93	1.58	2.30	-	-
Jodhpur	0.63	0.0	0.95	0.0	-	-
Sholapur	0.77	0.0	1.62	2.83	1.38	-
Castor[3]						
Anantapur	-	-	-	1.11	0.97	0.23
Jodhpur	-	-	-	1.35	0.93	0.52
Sholapur	-	-	2.51	1.16	0.88	0.38
Pigeonpea						
Akola	-	-	-	1.33	2.28	-
Anantapur	0.56	0.96	1.15	1.18	-	-
Sholapur	-	0.0	2.38	1.97	0.01	0.23

(Contd.) TABLE 7 : Experimental yields (t/ha) of oilseeds and pulse crops at different locations during different years.

Crop/location	Experimental yield (t/ha) in different years					
	1971-72	1972-73	1973-74	1974-75	1975-76	1976-77
Groundnut[1]						
Chickpea						
Indore	1.17	0.81	1.73	-	.	.
Sholapur	1.10	0.9	1.50	1.62	.	.
Guar (Cluster beans)						
Hissar	.	.	0.90	0.85		
Jodhpur	.	.	1.99	1.06	0.42	0.83

1. Groundnut-dry pods yield.
2. Indicates that experiment was not conducted.
3. Castor-grain yield.

Source: Tabulated from review reports of rainy and post-rainy season data of AICRPDA centres for different years.

climatic enviornment, i.e., low and unstable rainfall, and its interaction with spatially variable land-resource base. To enable scientists and policy-makers to overcome these disincentive effects, we need to clearly express the unavoidable implications of agro-climatic environment on the research strategy for dry-farming.

Need for Low Expectation Profile

Because of environmental constraints, dramatic increases in crop yields—comparable to those witnessed in wheat, and to some extent in rice-based green revolution areas—are simply not possible in the case of dry-farming areas and crops. Despite scientific innovations crops cannot perform beyond the limits imposed by the agro-climatic environment, particularly moisture availability. Hence, one has to be content with relatively less impressive but gradual improvements in crop yields.

Recognition of Location Specificity

As the spatial and temporal heterogeneity of agro-climatic environment persists in the absence of irrigation as a homogenising factor, the chances of a technological breakthrough which could find wider applicability even in larger tracts within dry-farming regions are fairly limited. Hence, one has to look for a range of location-specific breakthroughs to suit specific situations within the dry-farming zone.

Interpreting soil and climatology data and harmonising the results to enable uniform comparisons would help. To date, not much effort has been made in this direction.

Multioption Prospective Technology

The agro-climatic environment of dry-farming offers a complex of favourable and unfavourable crop production opportunities that change both spatially and temporally. Technology relevant to such situations should have components that help in exploitation of favourable opportunities and in maximising the scope for adjustment during unfavourable conditions. The technology should generate a large number of options for the farmer to adopt depending upon the circumstances of the cropping season. Narrowly conceived prospective technologies, such as those directed towards improving grain yields alone, cannot fulfil the total requirements of a relevant technology for dry-farming areas. Similarly, conventional criteria of technological breakthroughs based on yield levels may prove inadequate in these areas. The criteria of success should also include the number of total options generated by the technology to adapt to fluctuations in the agro-climatic environment. Seemingly minor practices from the viewpoint of increasing grain yields alone may be important in influencing the total farming system. A variety of crop options, mid season corrections, changes in input-use intensity at critical times, etc., are some examples. Alternative uses of land involving agro-forestry, watershed-based system of farming, etc., are other options.

Widening the Research Infrastructure

Generating technologies which offer multiple options to optimise the returns from areas with unstable agro-climatic conditions is a difficult task. It calls for basic changes in approach and infrastructure of the agricultural research system in dry-farming areas. The conventional pattern of concentrating research activity at a few selected locations and emphasis on 'top-down' approach to technology diffusion may not generate relevant technological options. Multi-location research must be complemented by extensive on-farm experimentation at sites determined after critical assessment, based on soil and climatic data. The latter will help make technology adoption more relevant and capture the traditional wisdom that dryland farmers have accumulated over generations. These changes may face two major constraints: it would make the cost of dry-farming research higher than the level to which policy-makers are accustomed; and, this approach may militate against the biases that scientists now have for conceiving, developing, and refining technological options within the confines of research farms.

As generating a worthwhile technology is difficult in the face of the unstable environment of dry areas (compared to areas well supported with water) its costs are higher. Because of the magnitude of the task and the difficulties encountered, dry-farming research cannot be a low-cost option. However, this may be added that multi-

plication trials and on-farm experimentation which add to the cost of dry-farming research would also help imporve the relevance of technology and reduce the gestation period of both generation and transfer of technology. This may make the whole effort cost-effective. Furthermore, dryland technology through resource-centred components (e.g. moisture conservation measures) besides helping identification of suitable cropping systems etc., also attempts to stabilise the environment for crops. In the case of irrigated areas, the environment is stabilised through irrigation schemes. In the former, unlike in the latter, the cost of stabilisation of environment becomes part of the cost of research. If this component of the cost is treated differently, the overall cost of dry farming research may not appear too high.

To negate the bias that researchers have for work at research stations and experimental farms, they should be reoriented on the emerging focus of research, and incentive systems for them should favour problem-solving field research.

Dry-farming Research : Past Efforts

Dry-farming research has been one of the most neglected areas in terms of research resources allocation. In this section we will discuss the approaches and strategy of efforts made to develop dry-farming technology. These research efforts could be viewed in two time frames: 1. research prior to 1970, and 2. research since 1970. This is because the approach to dry-farming research has undergone significant quantitative and qualitative changes since 1970. For our discussion, the post-1970 research effort is considered as the present approach.

Bombay Dry-farming Era

The first ever effort to evolve solutions based on available soil moisture conditions was initiated through dry-farming research at 5 locations by the Indian Council of Agricultural Research (then called Imperial Council of Agricultural Research) in the 1930s. The five locations were drought-prone areas of Sholapur and Bijapur (in former Bombay State), Hagari (near Bellary in Madras State), Raichur (Hyderabad State), and Rohtak (Punjab State). This was a short-lived effort and it ended when all activities unrelated to the war efforts of the British government were terminated in the early 1940s (Kanitkar et al., 1960), much before scientists could fully conceive of relevant technological options. The recommendations evolved through multilocational work during this period were described as Bombay Dry-Farming Practices (BDF). BDF was mainly directed to prevention of soil erosion and conservation of moisture through mechanical measures (e.g., contour bunding) as well as crop cover. These measures were supplemented by suitable agronomic practices (e.g., shallow preparatory tillage, periodical deep ploughing, interculturing, low seed rate, wide spacing of crops, etc.) to raise farm production. BDF was strongly supported by several states through demonstration at 45 dry-farming projects. This attempt, however, failed to click for several reasons.

Firstly, as a research strategy, BDF offered few new options. It did not have any new biological component in terms of high-yielding seeds. Manurial and cultural practices in most cases were already known to the farmer. Mechanical measures (contour bunding, periodical deep ploughing, etc.) unaccompanied by new crops responsive to conservation measures failed to interest the farmers. An increase of 15 to 20% over the then prevailing low crop yields of 200 to 400 kg/ha was too marginal to enthuse farmers to adopt mechanical measures (Randhawa and Venkateshwarlu, 1979).

Secondly, even the major component of BDF, namely contour bunding, was never evaluated vis-a-vis farm-level realities. Since contour lines seldom converged with farmers' property lines or field boundaries, farmers opposed bunding on contours. As a compromise, field border bunding (with little technical basis for it) was supported by most of the states, led by Maharashtra in the post-independence period (Jodha, 1979). As a programme bunding suited the target-oriented district or state administration in dry areas as the physical structures were tangible; it was also practised for the vast potential it offered for misuse of resources. By 1973-74, 15 million ha were covered by soil conservation (bunding) in India. This measure did not have a marked impact on the productivity of dry-farming as it was adopted more as a famine relief measure rather than a production-oriented programme (Jodha, 1979).

The premature stoppage of work and the absence of follow-up research on components of potential technologies identified by BDF also contributed to its failure.

Soil Conservation Research

While propagation or extension of BDF, mainly bunding, became a part of relief activity in several drought-prone areas, research on the subject was confined mostly to ravine-affected areas covered by Soil Conservation Research Centres started since 1954. Though some of these centres did include dry-farming practices, their focus was mainly on conservation aspects. The focus of organisations like the Central Arid Zone Research Institute established during this period (1959) was also initially on resource conservation and afforestation research. The work of some of these centres (e.g. at Bellary in Karnataka) did help in understanding runoff patterns, behaviour of soils in post-rainy period, etc., which initiated thinking on research to match crop varieties with the resources that farmers could muster (Anon, 1980).

Early HYV Era

The work on crop breeding and varietal improvement done earlier and accelerated in the early 1960s covered some prominent crops grown in dry-farming areas. The hybrids of sorghum, pearl millet, maize, and improved varieties of other crops evolved did help some pockets within these areas. The excellent work carried out under All India Coordinated Research Project on Sorghum, Pearl Millet etc. was incidental to dry-farming areas. There was no integration of crop-based research with resource-based research (done earlier), nor was there any opportunity or mechanism to assess the relevance of new crop technologies with the agro-climatic variabilities of dry-farming areas. Consequently, hybrids of sorghum and pearl millet released in the late 1960s did not spread beyond well-watered areas. Their standardised management practices could not offer the degree of flexibility that dry-farming needed. Moreover, the heavy incidence of disease and seed adulteration adversely affected the adopters of hybrids during the late 1960s. This led to a large-scale withdrawal of farmers from HYV- programmes even in progressive areas like Gujarat (Jodha and Dharap, 1970).

Thus all research efforts till 1970 either treated the problem of dry-farming areas only partially or suggested generalised technologies evolved essentially for well-endowed stable environments. As a consequence technologies relevant to dry-farming were not available to dryland farmer till the early 1970s.

Present Efforts and their Approach

If the conservation-oriented work mostly on ravines and deserts is excluded, the renewed effort to develop technology for dry-farming areas in India was initiated about 30 years after the BDF experience. Alarmed by the consequences of the green revolution completely bypassing dry-farming areas, research on dry-farming was intensified. The effort was directed to achieve a technological breakthrough like the one that ushered the green revolution. In 1970, AICRPDA was initiated, and AICRPs involving major dryland crops were strengthened. In 1972, ICRISAT was established (with headquarters in India) to serve semi-arid tropical areas all over the world. The focus of these organisations was to increase and stabilise food production in drylands by evolving low cost technologies to match the means and needs of dryland farmers.

Looking towards the research infrastructure and approaches, it seems that since the 1970s, most of the factors wich inhibited generation of improved dry-farming technologies in the past have largely been overcome. This is partly due to improved resource allocation to dry-farming research and increased availability of components (including germplasm for plant breeding) for prospective technologies. The latter has been greatly helped by pooling of past experiences.

Complementarity of National and International Effort

The increased emphasis on dry-farming research in India was complemented by similar emphasis at the international level with the establishment of ICRISAT. Though ICRISAT's geographical mandate is not confined to India, its research does complement the work by Indian organisations. Ready availability of germplasm and breeding material to Indian scientists, the collaborative work by ICRISAT and Indian research organisations, greater facility for professional

interaction, and multilocation testing are some advantages emanating directly from ICRISAT's research activities in India.

In view of the free flow of ICRISAT research results to all relevant areas it is difficult to estimate the extent of its benefits to any specific mandate country. Some idea of this phenomenon can be had from an analysis of ICRISAT's resource allocation in relation to its mandate crops–ICRISAT's mandate extends to 49 countries with semi-arid tropical areas. India accounts for nearly 13% of the area and more than 60% of the population of the SAT world. India's share in the total production of these crops in the SAT regions and share of ICRISAT's resources during 1980 (in terms of principal scientist equivalents) allocated to these crops in India respectively are: sorghum 34% and 35%; pearl millet 35% and 42%; chickpea 84% and 71%; pigeonpea 97% and 100%; groundnut 49% and 82% (von Oppen and Ryan, 1985). During the same period of the total resources allocated by ICRISAT to farming system and economics programmes, 58% were spent in India. Thus, a substantial research investment by ICRISAT takes place in India, partly because ICRISAT has its headquarters in India. The resources allocated to research at ICRISAT Centre in India have spillover effects for other SAT regions. Through the availability of material and methodologies developed at ICRISAT Centre to other countries, and through prolonged work by Centre-based scientists in other countries, considerable benefits of ICRISAT resources spent at the headquarters are transferred to other SAT countries. But that does not reduce the benefits of ICRISAT work to dry-farming areas in India.

Climate as a Source of Growth

Climatic variability became a concern for policy makers only during drought years. Hence, a climate characterised by droughts as well as abundant or normal rainfall was considered only as a source of distress. The positive aspects of climate (i.e. frequency of good rain years) tended to be overlooked in public intervention measures such as protective irrigation schemes or drought relief. The renewed research efforts in dry-farming areas incorporate a strong component of agro-climatology, and lay greater emphasis on harnessing the favourable opportunities offered by climate to dry-farming areas (Sivakumar and Virmani, 1982). Depending solely on local soil-moisture resources, as against water from distant resources, the prospective technologies attempt to maximise benefits from normal rain years. Crop and resource management devices are designed to take two crops from the same land in some areas during normal years (Ryan et al., 1982, ICRISAT, 1981). Through a variety of contingency measures and mid-season corrections, the flexibility of the farming system is increased to accommodate the impact of weather variability, especially during low rainfall years (Krishnamoorthy et al., 1977).

Integration of Resource and Crop-centred Technologies

The new approach to dry-farming research takes an integrated view of the farming system; the emphasis is both on land and water resource management, and on crop improvement technologies (Kanwar, 1976). Furthermore, unlike the single component of contour bunding in BDF, several measures–such as broadbed and furrows, graded bunds, broad-based terraces, contour cultivation, ridging on flat, vertical mulching, and varying degrees of land smoothing–are tried to suit different soil-rainfall conditions. In situ moisture conservation, proper drainage, runoff collection and recycling of water for supplemental irrigation are tried (ICAR, 1981; AICRPDA, 1982). To match the multiple alternatives for resource conservation and management, the agro-biological component-cultivars and varieties of different physiological characteristics in large number–are also developed.[2] This helps in evolving a greater range of options to suit various areas.

The range of options is further widened by a variety of combinations and sequences of crops, with varying growth habits and moisture requirements. Thus research on soil moisture management, plant breeding, cropping systems, and agronomy covers all aspects of dry-farming in dry areas (ICAR, 1981; Binswanger et al., 1980).

Multilocational Testing

In keeping with the location specificity of dry-farming, the research work is conducted simultaneously at several locations. The locations are identified on the basis of key parameters such as soil types, rainfall amounts and distribution, etc. AICRPDA has 23

centres in various parts of rainfed India. This is supplemented by multilocational testing facilities, including minikit trials conducted by AICRPs on dry crops like sorghum, pearl millet, and pulses. ICRISAT works in collaboration with national organisations in India, and those in other SAT countries, and has multilocational testing facilities at several places. This also helps in generating a larger number of technological options to suit different agro-climatic conditions.

Mechanisms for Farm-level Verification

Multilocational experimental facilities help in evaluation and adaptation of prospective technologies across ecological zones within the dry-farming regions. The final test of technology, however, is its relevance and viability at the farm level. To facilitate this, current dry-farming research also undertakes testing of prospective technologies on farmers' fields. This is done through on-farm trials and a number of diagnostic experiments in villages, national demonstrations, pilot development projects attached to research centres, operational research projects, lab-to-land programme etc. The objective is to get feedback, to be followed by amendments in the technological recommendations (Sanghi, 1982; Ryan et al., 1982; Sarin and Walker, 1982).

Special-Problem Focused Research

Besides the integrated research on crop improvement and resource management considerable resources are devoted to problem-specific work. This may include research like that on Striga (a deadly weed that particularly affects sorghum), on disease and pest problems specific to dryland crops which depress the yields despite other yield-raising factors, and land- and water-management practices. Work on such problems constitutes an integral part of technology development for dry-farming areas (ICRISAT, 1982).

Having highlighted the salient features of the approach to dry-farming research since 1970, it would be appropriate to comment on some achievements that resulted from this effort. Since the results are analysed and reported in several other accompanying papers in present volume (i.e. by Singh; Walker et al.; Mruthyunjaya; Sanghi and Vishnumurthy), this paper only highlights the gaps or unattended issues in the present approach to dry-farming research.

Some Unattended Issues

The present research strategy to develop technology for dry-farming areas is well integrated and has a sharper focus than earlier approaches. A closer look at the experimental designs and priorities, however, indicates a number of unattended issues. These relate to inadequate understanding and analysis of the physical and socio-economic environment and use of such understanding in designing new technologies.

Inadequate Analysis of Physical Environment

Agronomists today possess more detailed data on soils, climatic variables, and crop characteristics. They also have greater skills and facilities (through computers, etc.) to analyse, integrate, and effectively use these data. The work in most areas has not progressed beyond the documentation and conceptualisation stages. The results available so far are not in the form of easily usable guidelines for generating location-specific or weather-specific technologies.

Indifference to Farmer Circumstances

Even though the final user of prospective technologies is the farmer, and his traditional farming practices can offer useful information for researchers, an understanding of the farmers' circumstances and practices is often not fully utilised as an important input in developing new technologies. The survival mechanism that farmers use under an unstable farming environment may indicate suitable elements to be integrated in technology development work. This somehow is not appreciated as the following illustrations depict.

Strong Bias Towards Crop Production

Both crop- and resource-centred research activities are directed toward improving crop production. Even when the research is in the area of farming systems, the focus is on improving crop production. At the farm level, crop farming and livestock farming complement

each other and, as a consequence, the farmer finds good use for crop byproducts. With their concern for more grain yield, crop technologists do not give enough weight to the benefits dryland farmers derive from crop byproducts.

Traditional farming systems acquire some degree of stability through the farmer's dependence on trees and bushes which (unlike crops) are not greatly influenced by temporal variability of rainfall. The integration of crops, livestock, and trees (or perennial bushes) offers a dependable basis for survival in the context of unstable crop farming. Research can transform this survival system into a growth mechanism. The present approach to technology development for dry-farming areas is inadequate to accomplish this. While some work on forage, grasslands, forest, and silvi-culture has been in progress, it is seldom integated in farming systems research. Another element in the survival mechanism which farmers have evolved is the integration of common property resources (CPRs) and private property resources (PPRs) for sustenance of livestock and cost-free input supplies for farming (Jodha, 1983). Current research is not sensitive to this issue. The integration of livestock, trees, bushes, and CPRs in prospective technological options will not only help generate more options, but also help in better protection and utilisation of the environment.

On Farm Research Symbolic

The new approach to dry-farming research has adopted some mechanisms to evaluate prospective technology in farmers' situations. Notwithstanding the impressive research and development work done at some locations like Indore, both in terms of its extent and depth, the effort is seriously inadequate. Furthermore, even when on-farm testing is undertaken, the researchers still tend to favour a top-down rather than bottom-up approach to technology generation. Potential technology is conceived, developed, and refined (through feedback) at research stations only. The involvement of the farmer or his circumstances at the stage of conception of relevant technological solutions to his problems is not encouraged. Thus, some of the vital aspects of traditional farming systems tend to be ignored while formulating an integrated approach to dry-farming research.

Risk and Flexibility

Traditional farming systems are highly flexible and this is reflected in the number of farming practices and resource-use patterns in vogue. They range from intercropping to methods of crop harvesting (Jodha and Mascarenhas, 1985). Through these practices, farmers try to generate more options within the confines imposed by agro-climatic conditions. Research based on scientific knowledge of new crops and resource management principles can help multiply the options for the farmer. Notwithstanding some research on impact of date of sowing and crop sequences etc. the technological recommendations are often too costly, standardised, and rigid to offer the required degree of flexibility to guard against risk (Rastogi and Annamalai, 1981).

The disregard for 'stability' is evident from the fact that at the selection level of cultivars and varieties, those with low but stable yields are often dropped in favour of those with high yields. In certain cases, the experimental results of poor rain years are completely dropped while analysing the performance overtime of certain components of technology.

Conclusion

Dry-farming research has been one of the most neglected areas of research as agro-climatic variability tends to constrain resource allocation. An understanding of the implications of agro-climatic constraints can help evolve more appropriate approach and strategies for dry-farming research. Since the early 1970s, dry-farming research has become more sensitive to these implications. Owing to better infrastructure and improved resource allocation at the national and international levels, as well as availability of a greater number of technological components, dry-farming research is today better equipped to generate technologies to suit different farming situations. The present approach needs to be further revised to make interactive and effective use of information on environmental variables as well as farmer realities while formulating research strategies.

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Footnotes

1. Since 1985 AICRPDA has been converted into a fulfledged Central Research Institute for Dryland Agriculture.
2. ICRISAT has a huge collection of germplasm of major dryland crops. This includes over 20000 lines of sorghum, 14000 of pearl millet, 12000 of chickpea, 10000 of groundnut.

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