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ADVANCING DRYLAND AGRICULTURE: PLANT BREEDING ACCOMPLISHMENTS AND PERSPECTIVE*

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INTRODUCTION

At the very outset, let us pay our homage to the memory of the founder of our Society, Dr. Benjamin Peary Pal, who left us for the heavenly abode on September 14, 1989. Genetics is a creative science and plant breeding creates superior forms. Be it wheat breeding, enhancing the beauty of the roses, nurturing agricultural and environmental sciences, refreshing the human environment with his ever fresh sense of dignified humour, combining science and statesmanship—creativity had been the hallmark of Dr. Pal. Let us pay our reverence to his foresight and extraordinary creative abilities. Wheat and Pal are synonyms in India.

While wheat furnished the leadership for irrigated agriculture, rainfed agriculture lagged behind. Let us, on this occasion, address ourselves to this risky endeavour of rainfed agriculture covering nearly 70% of the Indian agricultural canvas.

Agricultural systems represent induced changes in the natural balance. That such induced changes have not made a significant impact in improving the productivity and sustainability in dryland agriculture of the arid and semiarid tropical environments; that India's Green Revolution largely bypassed nearly 70% of its rainfed lands where productivity is low and risk-prone; that it continues to be near static and needs a change for promoting overall agricultural growth and equity; that without investments matching those in irrigated sector to modify its resource base, dryland agriculture would not advance are some of the statements frequently made by scientists and science administrators.

We continue to look at dryland agriculture as prone to yield risks, price risks, and resource risks. The weak resources of the farmer, the low value crops predominating dryland systems, the lack of multiple productivity options and institutional support have been frequently cited as constraints in the way of progress. Technological changes and their interactions with ecological situations, economic and social factors largely determine the magnitude of change in the dryland agricultural production systems. Plant manipulations

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are more potential and permanent compared to environmental modifications and together they could lead towards stability. It shall be my endeavour to analyse the present status of dryland agriculture and develop a perspective for its future in India.

AGRICULTURAL RESEARCH IN DRYLANDS: BRIEF HISTORY AND ANALYSIS

India's cultivated land varies between 141–143 million ha, of which 68% (95-96 million ha) is under rainfed agriculture. Compared to the significant changes in production and productivity of irrigated wheat and rice during the Green Revolution era, productivity changes in the vast rainfed belt are of a lesser magnitude. Nevertheless, the changes witnessed have been in the positive direction. The pace of agricultural advancement of this region needs acceleration and is vital to the overall agricultural growth and development. The history of dryfarming research may be considered in four phases, the salient features of which are briefly summarized:

(1) *Bombay dryfarming research (1930)*: Soil erosion control and moisture conservation through contour bunding and crop cover supplemented by agronomic practices (periodical deep ploughing, shallow preparatory tillage, interculturing, low seed rates, wide spacing etc).

(2) *Soil conservation research (1954)*: Understanding runoff patterns; matching crop varieties with farmers' resources etc; establishing soil conservation research centres.

(3) *High yielding varieties programme (1964)*: Growth rates of rainfed kharif sorghum matched those of irrigated wheat and rice due to development and spread of hybrids; advances and subsequent setback in the spread of pearl millet; limited success with pulses and oilseeds.

(4) *Establishment of All-India Coordinated Research Project on Dryland Agriculture (AICRPDA) (1970) and ICRISAT (1972)*: Their studies emphasize greater integration of resource and crop based technologies.

The watershed approach is being projected as the main plank for overall improvement of dryland agriculture in India in the years to come; the observations of Walker and Ryan [1] on watershed studies are briefly summarised below:

(1) The cost benefit ratios of water harvesting and supplemental irrigation were not attractive.

(2) The benefit of groundwater recharge are difficult to quantify.

(3) Frequently, water present in the pond when not needed, and absent when needed.

(4) Irrigating low value crops during the season had no justification.

(5) Available sealants were not cost effective in controlling seepages.

(6) The more beneficial watersheds were in the assured rainfall vertisol regions where once in three years, following soybean, water was available for wetting seed bed of wheat crop.

(7) Of the components of the watershed technology package, e.g. broad based furrows, field and main drainage channels, improved varieties and cropping systems, modest doses of fertilizers, dry seeding before onset of monsoon, placement of seeds and fertilizers and plant protection, only selective components such as plant protection in case of some crops, adoption of hybrids of sorghum and new crops like soybean have only been accepted.

Walker and Ryan [1] remarked, "it is hard to see how the marriage of technically optimal land and water management to biological technology is going to alter these perceptions."

Amongst these four stages, the high yielding varieties programme (HYV) had selective impact on productivity of drylands, especially with kharif sorghum, pearl millet, and spread of some superior varieties of pulses and oilseeds.

The observations of Walker and Ryan [1] on technology design for drylands may be summarized as follows:

(1) Land improvements, central to watershed approach, have several limitations and do not compare favourably with investment in well irrigation.

(2) Technology targetting towards vulnerable groups is ubiquitous; gradient approach to identify and promote practices compatible with local circumstances are more meaningful.

(3) Direct employment consequences of technology change in drylands are nearly absent.

(4) Productivity gains and increasing commodity supply will have a better impact on nutritional status than genetic improvements in nutritional quality.

(5) Reduction of variance for a given level of yield would not reduce fluctuating household incomes.

(6) Mean yield and profitability should remain front and centre on the agenda of the objectives.

THE APPROACH

It is against this background that future dryland research needs to be designed. Alternative research tools and models are being developed keeping in view the concept of sustainability together with productivity. Sustainability is a somewhat elusive concept, and different definitions are available. The FAO and University of Nebraska definitions are reproduced:

"Sustainable agriculture should involve the successful management of resources for agriculture to satisfy changing needs while maintaining or enhancing the quality of the environment and conserving natural resources" (FAO/TAC).

"A management strategy which helps the producer to select hybrids and varieties, cultural practices, soil fertility progress and pest management approaches which reduce costs of purchased inputs, minimize the impact of the system on the immediate and off-farm environment, and provide a sustained level of production and profit from farming" (University of Nebraska).

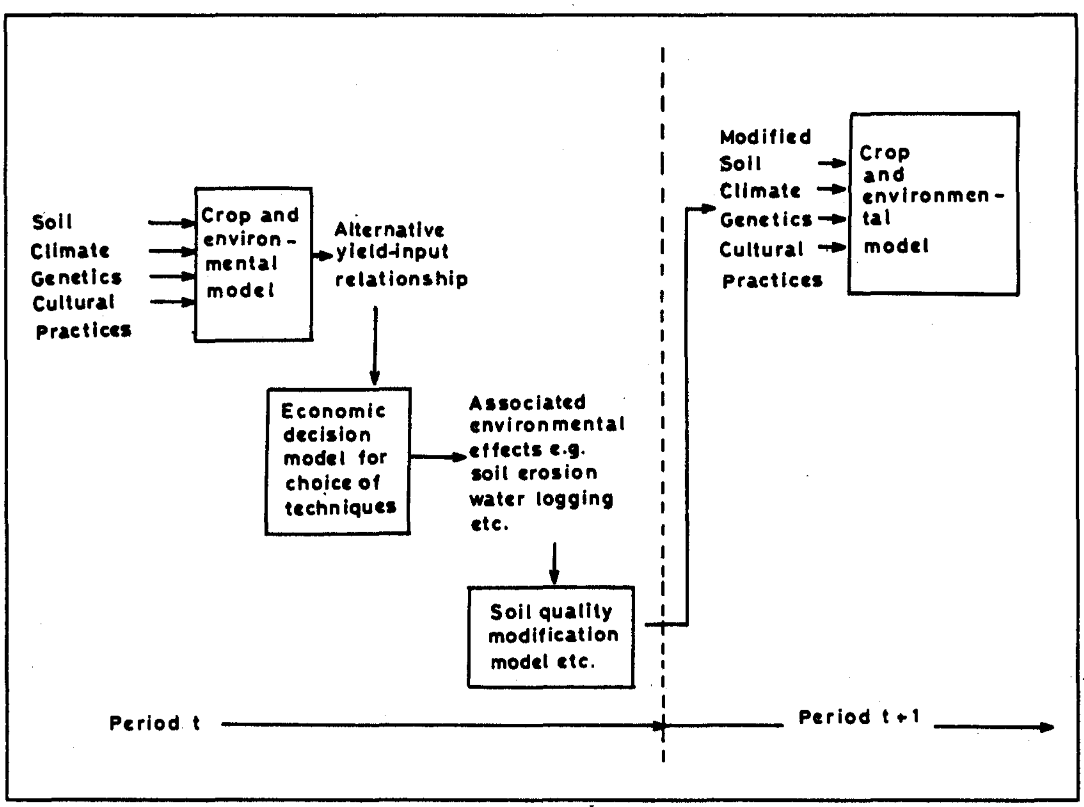

Fig. 1. Schematic diagram of analytical elements in the methodological approach of Ereshko et al. Source: Parikh, 1988, p. 41 (reproduced from IIASA publication).

With the Nebraska definition in view, one of the models developed by the International Institute of Applied Systems Analysis is reproduced in Fig. 1. Considering 1990 as the end of the period t, and with a critical analysis and understanding of the effect of our interventions in dry land agriculture on the resources and the output, which to a large extent has been elegantly analysed by Walker and Ryan [1], we could use this crop and environment model for the period t+1, may be about 10 years hence, to pursue the goal that "mean yield and profitability should remain front and centre on the agenda". It is with this objective and the current status of dryland agriculture in its totality that I approach the problem of advancing dryland agricultural production and productivity.

THE RAINFED BELT AND ITS SOILS

The distribution of the vast rainfed belt across the various states of the Indian Union is presented in Table 1.

Table 1. Major rainfed areas of India in 1984–85, million ha

	States	Net area sown	Net irrigated area	Rainfed area	Irrigated area (%)
(i)	Madhya Pradesh	19.205	3.010	16.195	13.9
	Maharashtra	18.047	1.964	16.083	13.1
	Karnataka	10.549	1.693	8.856	18.0
	Andhra Pradesh	10.486	3.522	6.964	36.6
	Rajasthan	15.215	3.204	12.011	22.2
	Gujarat	9.583	2.240	7.343	25.5
	Total	83.085	15.633	67.452	
(ii)	Uttar Pradesh	17.248	9.879	7.369	48.4
	Bihar	7.643	2.795	4.848	36.7
	Orissa	6.288	1.466	4.822	23.1
	West Bengal	5.341	1.980	3.361	26.1
	Assam	2.696	0.572	2.124	15.4
	Total	39.216	16.692	22.524	
(iii)	Tamilnadu	5.788	2.640	3.148	49.5
	Kerala	2.184	0.271	1.913	14.7
	Total	7.972	2.911	5.061	
(iv)	Punjab	4.189	3.621	0.568	90.5
	Haryana	3.616	2.189	1.427	63.6
	Himachal Pradesh	0.580	0.095	0.485	17.1
	Jammu & Kashmir	0.735	0.309	0.426	40.5
	Total	9.120	6.214	2.906	
(v)	N-E States	1.03	0.240	0.783	23.4
	Others	0.299	0.089	0.210	
	Total for India	140.715	41.779	98.936	30.7

States in category (i) represent the largest dryland belt of India's arid and semiarid tropics. The Northwestern arid zone with aridisols and low rainfall is a more fluctuating and risk prone environment for arable crops. The vertisol rabi sorghum belt of Deccan is also vulnerable. The vast vertisol belt of these states together with the Bundelkhand region of Uttar Pradesh receiving moderate to heavy rainfall and predominant kharif cropping (cotton-kharif sorghum) is the most potential belt for advancing crop production. The distribution of the assured and vulnerable portions of the vertisol belt of India under different rainfall regions is presented in Table 2.

The eastern and northeastern states in category (ii) have mostTof the lowland rice for which special rice production programmes have been developed. Under irrigation, sugarcane, wheat and rice–wheat systems are practiced. The productivity of rainfed kharif areas and kharif fallows of irrigated wheat belt has not witnessed any major change.

Table 2. Distribution of vertisol in different rainfall zones (area in million ha)

State	Area in different rainfall zones			
	500–750 mm	750–1150 mm	1150 mm	total
Maharashtra	10.00	11.22	3.35	24.57
Madhya Pradesh	0.16	8.51	7.85	16.52
Gujarat	2.40	1.81	2.28	6.49
Andhra Pradesh	1.96	2.66	2.35	6.97
Karnataka	5.97	0.76	0.11	6.84
Total	20.49	24.96	15.94	61.39

Under category (iii), dryland areas of Tamil Nadu served by the northeastern monsoon, are vulnerable.

States in category (iv) are largely irrigated. Himachal Pradesh, and Jammu and Kashmir are somewhat temperate. Category (v) represents the high rainfall regions of Northeastern India with specialized hill agriculture.

An analysis of the growth rates of these states for food production (Table 3) reveals that Maharashtra, in spite of being predominantly rainfed, has made good progress and serves as an example that rainfed nature by itself need not be a deterrent to agricultural progress. The black soil rainfed areas of Madhya Pradesh, Karnataka, Gujarat and Andhra Pradesh are showing signs of progress.

THE CLIMATIC DIMENSION

The major concern of the rainfed belt is its low productivity and sensitivity to climatic fluctuations, aberrations, catastrophies and possible climatic changes. India is divided into 34 meteorological subdivisions, 10 of which cover the black soil belt.

Rainfall is the most important parameter influencing crop yields. A deficiency of 26–50%

Table 3. Classification of Indian states by weather-adjusted rates of growth in foodgrains production and growth in total population: 1970–71 to 1984–85

Positive growth in production > population growth	Positive growth in production < population growth	Negative growth in production; population growth positive
Maharashtra (6.23, 2.22)	Jammu & Kashmir (2.31, 2.54)	Kerala (–0.38, 1.80)
Punjab (5.92, 2.15)	Gujarat (2.07, 2.37)	Tamil Nadu (–0.64, 1.65)
Uttar Pradesh (4.32, 2.26)	Madhya Pradesh (1.95, 2.27)	
Haryana (3.90, 2.65)	Assam (1.90, 2.76)	
Andhra Pradesh (3.16, 2.06)	Orissa (1.59, 2.18)	
All India (2.70, 2.24)	Bihar (1.25, 2.18)	
	Rajasthan (1.07, 2.87)	
	Karnataka (1.03, 2.35)	
	Himachal Pradesh (0.80, 2.10)	
	West Bengal (0.54, 2.09)	

Note. The figures in parentheses refer to growth rates (in %) of food grain production and population growth, respectively. Population (rural and urban) growth is estimated from the 1971 census and Registrar General's estimates for 1985.

from the mean precipitation of a subdivision is considered a moderate drought and that over 50% as severe drought. Similarly, an excess precipitation of 26–50% over the mean is flood and more than 50% severe flood. The probability of the frequency of occurrence of droughts and floods in the vertisol semiarid regions (Table 4) was nearly equal during the

Table 4. Droughts and floods (1871–1984) in the meteorological subdivisions of the predominantly vertisol belt

Subdivision/region with No.	Area (km^2)	Droughts			Floods		
		No. of drought years	probability of drought	No. of years of severe drought	No. of flood years	probability	No. of years of severe flood
18. East Rajasthan	147, 128	19	0.167	6	18	0.158	2
19. West Madhya Pradesh	232, 315	11	0.097	—	10	0.088	—
21. Gujarat	86, 034	23	0.202	9	24	0.210	3
22. Saurashtra & Kutch	109, 950	34	0.298	11	30	0.263	14
24. Madhya-Maharashtra	115,309	13	0.114	2	11	0.097	1
25. Marathwada	64.525	20	0.175	5	23	0.202	4
26. Vidarbha	97, 537	12	0.105	1	12	0.105	1
28. Telegana	114,726	17	0.149	—	18	0.158	3
29. Rayalseema	69, 043	22	0.193	4	20	0.175	6
32. North Karnataka	79,895	12	0.105	—	13	0.114	1

Source. Parthasarathy et al. [2].

period of study 1871–1984 [2]. While the damage resulting from droughts received considerable attention, damage due to excess rains, more particularly late (October) rains, did not attract similar scientific or political attention. In the black soil belt excess rains could be more damaging than moderate drought.

Rainfall fluctuations within 0.5 SD on either side of the mean are manageable without yield losses; fluctuations over this, particularly on the heavy rainfall side have been more damaging to cotton and sorghum and need further technological attention (Fig. 2). In case of cotton, square, bud flower, and boll shedding during rains and increased boll worm attack, and with sorghum, grain moulds and deterioration resulting in low quality grain are the consequences. These problems need further research attention.

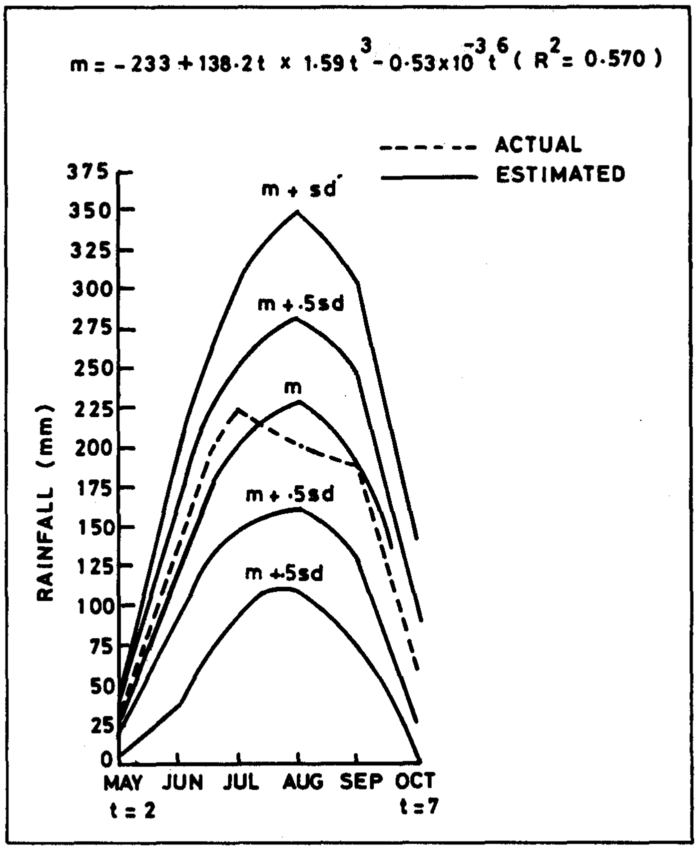

Fig. 2. Monthly rainfall distribution with deviations (Parbhani, Maharashtra, 1944-1986).

Figures 3 and 4 reveal the greater vulnerability of the rabi sorghum and bajra belts. The bajra belt is characterized by low rainfall and high evapotranspiration. The vulnerability of the rabi sorghum belt at Bellary and to a lesser extent at Sholapur is reflected in the water balance studies (Fig. 5). Fig. 6 shows the aberrations of rainfall, the commencement of cessation of monsoon. Continuous rainless days up to 31 days have been encountered during the monsoon season. These have been taken into consideration in developing the breeding philosophies for the hybrids and improved varieties of sorghum which have not failed under the worst droughts encountered. They were at a disadvantage if late and continuous rains were received in October.

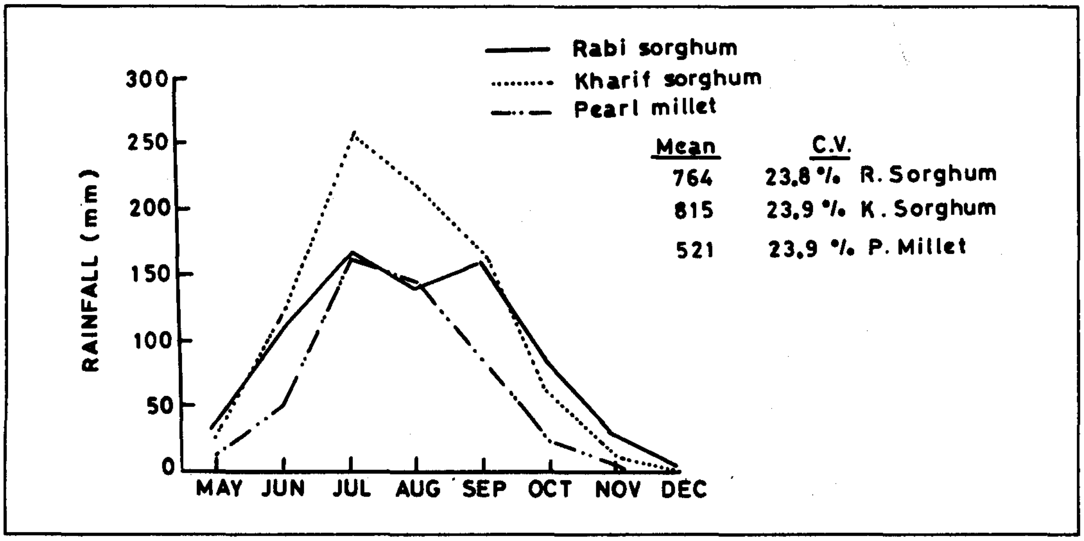

Fig. 3. **Rainfall distribution in rabi sorghum, kharf sorghum and pearl millet tracts in India.**

The effects of delayed monsoon and late sowings on yield of sorghum and pearl millet are depicted in Figs. 7 and 8. Sorghum is more vulnerable to delayed sowing and incorporation of shoot fly resistance will mitigate this to some extent. Consequent to the

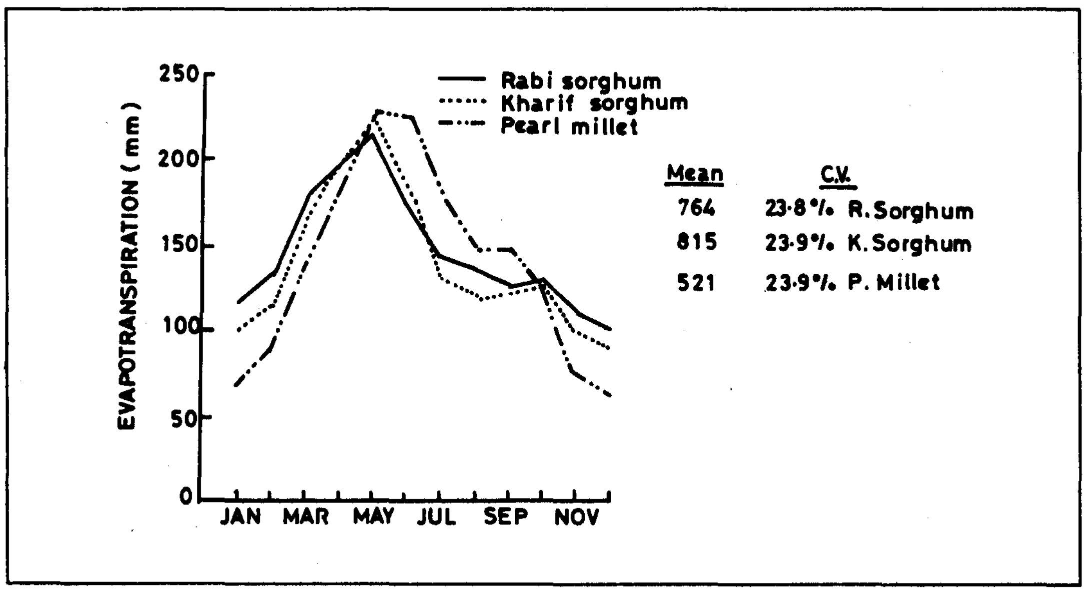

Fig. 4. **Potential evapotranspiration in rabi sorghum, kharif sorghum and pearl millet tracts in India.**

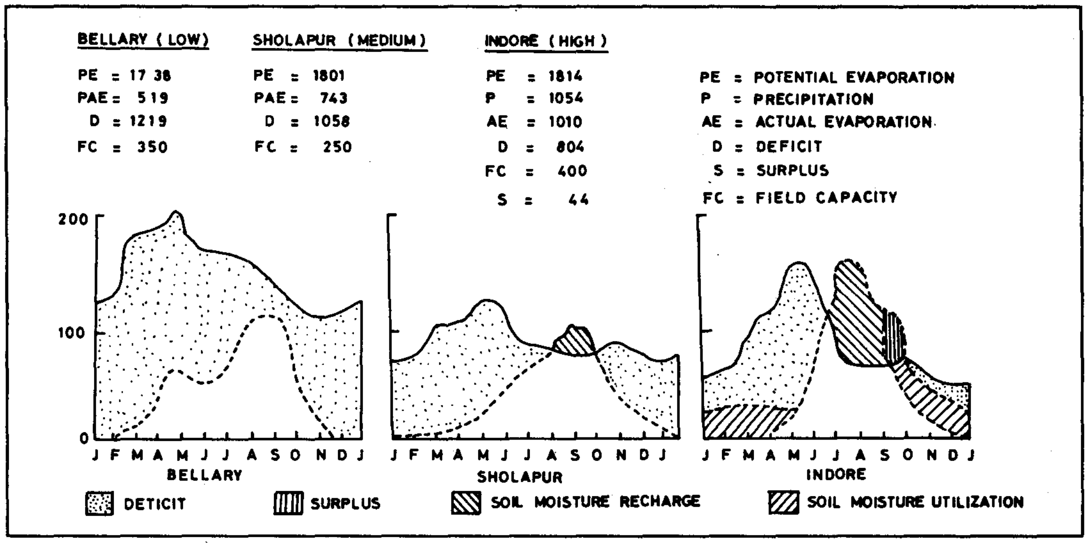

Fig. 5. Climatic water balance for low, medium and high rainfall zones in black soils (based on long-term meteorological monthly means, all measurements in mm).

crop modifications and improved practices with the HYVs, the effects of drought have been considerably mitigated and the Indian agriculture acquired resillience to subnormal monsoons (Table 5).

Decadal variability of rainfall in this century (Fig. 9) indicated that since 1940 there has

Table 5. Change in rainfall and foodgrain output

Year	Change in CRI from normal (%)	Fall in CRI with previous year as base, (%)	Fall in output over the previous year, %			Total Foodgrain output (million tons)
			kharif	rabi	total	
1964–65	+ 6.0	—	—	—	—	89.0
1965–66	–18.7	–23.3	–18.7	–17.7	–18.4	72.3
1978–79	+10.0	—	—	—	—	131.9
1979–80	–20.0	–27.3	–19.0	–13.7	–17.0	109.7
1981–82	+0.2	—	—	—	—	133.3
1982–83	–13.2	–13.4	–12.5	+9.2	–2.9	129.5
1985–86	–4.0	—	—	—	—	150.5
1986–87	–13.8	–10.2	4.3	–4.0	–4.3	144.0
1987–88	–27.5	–13.7	–8.8	+0.0	–4.9	138.4

Source. NCAER.

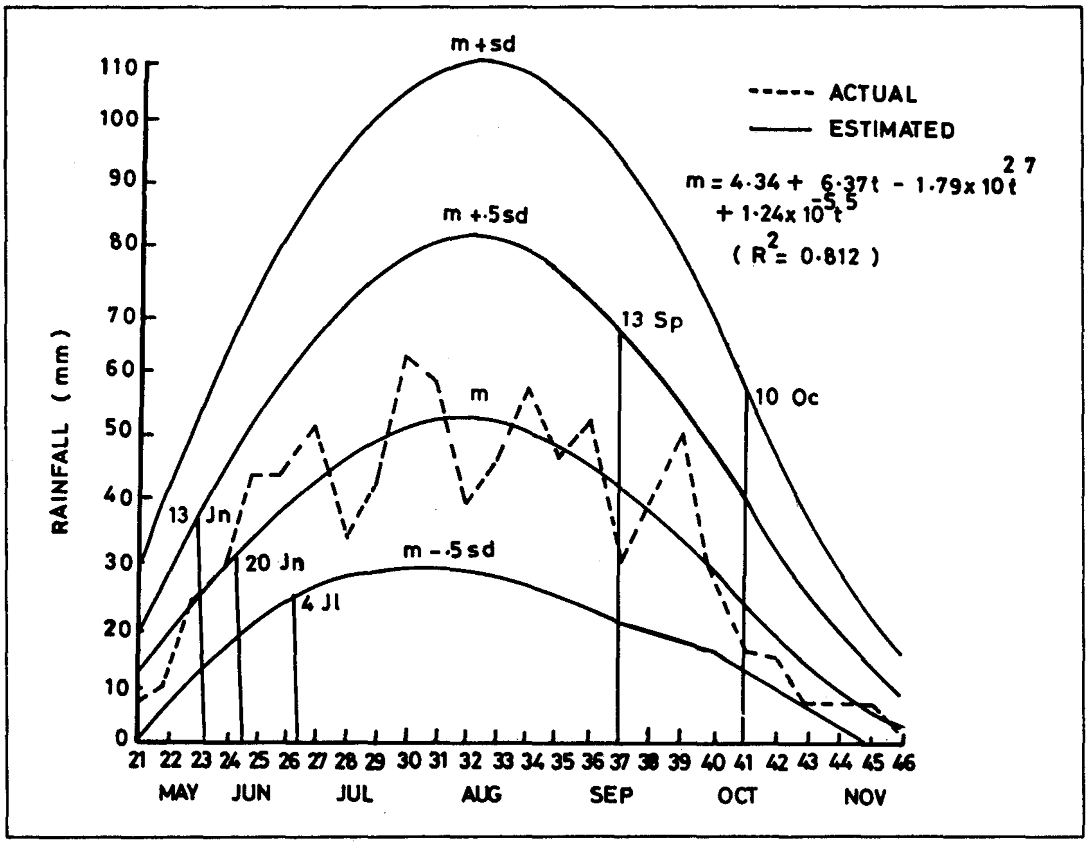

Fig. 6. Weekly rain fall distribution with deviations, com mencement and cessation (Parbhani, Maharashtra).

Table 6. Progress of production of some agricultural commodities in India (million tons)

Crop/commodity	1950–51	60–61	70–71	80–81	88–89
Foodgrains	50.82	82.02	108.42	129.59	170.25
Rice	20.58	34.58	42.22	53.63	70.67
Wheat	6.46	11.00	23.83	36.31	53.99
Coarse cereals	15.38	23.74	30.55	29.02	31.89
Grain legumes	8.41	12.70	11.82	10.93	13.70
Oilseeds	5.16	6.98	9.63	9.37	17.89
Cotton (m. bales)	3.04	5.60	4.76	7.01	8.69
Jute (m. bales)	3.31	5.26	6.19	8.16	7.70
Sugarcane	57.05	110.00	126.37	154.25	204.63
Potato	1.66	2.72	4.81	9.67	14.89
Tobacco	0.26	0.31	0.36	0.48	0.49
Coconut (m. nuts)	35.82	46.39	60.75	57.20	81.61

been a declining tendency together with an increase in the coefficients of variation [3]. The drier or wetter monsoons or extremes have been related to the ENSO (El Nino-Southern Oscillations) and depend on phase locking between the two events.

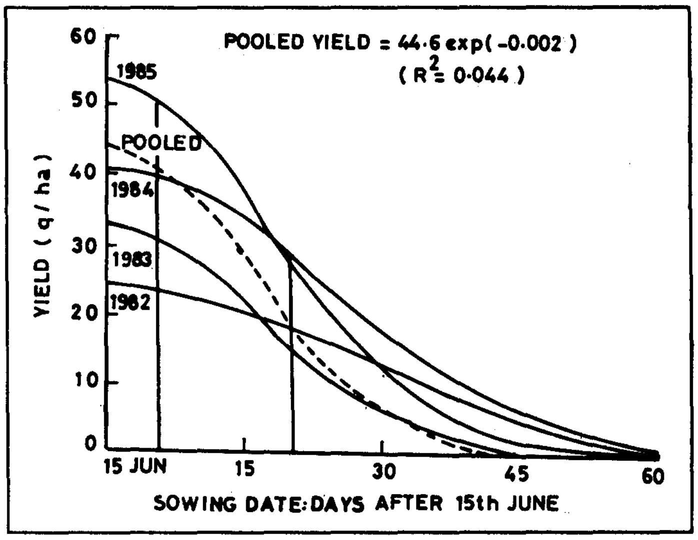

Fig. 7. Relationship between sowing time and yield of kharif sorghum.

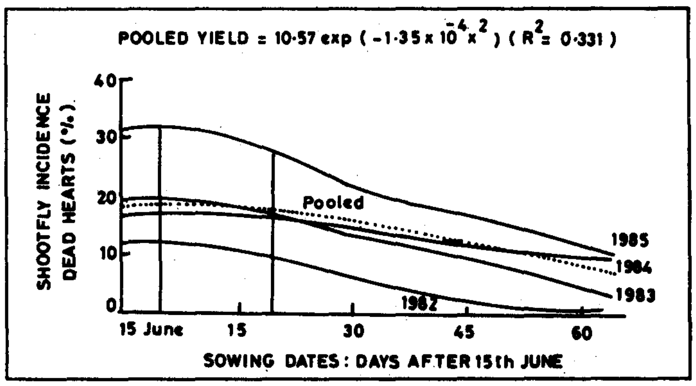

Fig. 8. Relationship between sowing time and yield of pearl millet.

In the last 100 years, globally averaged annual surface air temperatures have increased approximately by 0.5°C. If this variation rises to 1°C, throughout the year air temperature decreases in the east of the central part and N–W India. The effects are likely to be more noticeable in N–W India during monsoon.

Preliminary estimates of climatic changes in India [4] consequent to limited global warming indicate that during June–August and September–November precipitation is expected to increase along the west coast, and in most of the parts of Northern India increased precipitation might result. In the eastern parts of the subcontinent, including Andhra Pradesh and Orissa, precipitation might decrease slightly. During the September–November period also, the situation is expected to be similar except that rainfall may increase a little. The consequence of this is that during the monsoon season, indications are that rainfall may increase over the major parts of India. In general, the climatic changes are likely to be more favourable to the rainfed lands. Crop improvement programmes have to take cognisance of the impending changes.

COMMODITIES, CROPS AND PRICES

Cereals dominate the production system of dryland agriculture, followed by pulses and oilseeds. The progress in production of various crops and commodities is given in Table 6; and their approximate total area and the proportion of rainfed areas in Table 7. The growth rates of rainfed crops during the Green Revolution era are presented in Table 8. During the period 1967–68 to 1988–89, the areas decreased under all coarse cereals, chickpea and cotton. The productivity gains, though moderate, are positive in all cases. The yield gains are almost entirely a result of the spread of high yielding hybrids and varieties (Table 9).

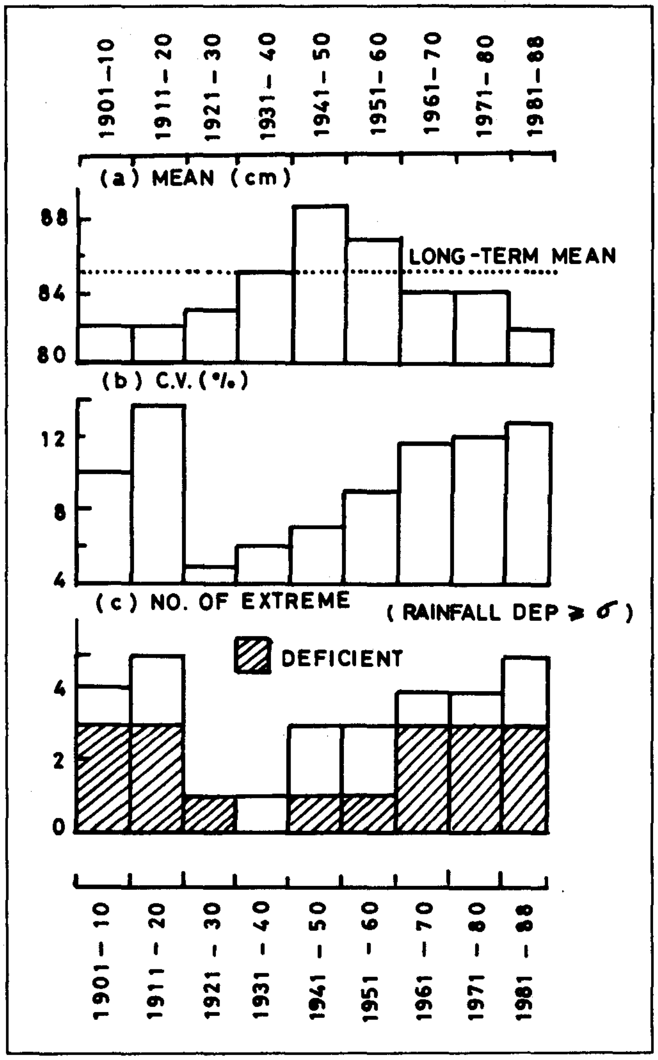

Fig. 9. Decadal variability of Indian summer monsoon rainfall (1901-1988): (a) mean, cm; (b) coefficient of variation; and (c) number of extremes (R. K. Verma, 1990).

The growth rate of kharif sorghum was particularly impressive and was as good as wheat till the early 1980s and influenced overall sorghum production. Later it started stagnating.

The possible reason for reduction in the area of coarse grains is the decline in per capita consumption in the rural as well as in urban sectors. Data from National Sample Survey reveal, in the specific case of sorghum, that per capita consumption declined in all the major sorghum growing states of Maharashtra, Karnataka and Andhra Pradesh. In Maharashtra, sorghum's share in total consumption fell from 60 to 45% between 1977–78 and 1986–87. Compared to wheat and rice or pulses and oilseeds, price increases of coarse cereals have been moderate (Tables 10, 11). In case of sorghum, the price rise of fodder was much greater compared to price rise of grain sorghum, resulting in reduction of total returns in case of the dwarf and semidwarf high yielding hybrids. In the mid-1980s, the grain: fodder price ratio declined from about 6.0 to 3.0%. During 1975–79, the share of fodder value was reported 0.42, whereas by 82-86, it rose to 0.58. Introduction of irrigation, addition of crops like soybean, and greater attention to pulses and oilseeds resulted in reduced areas under coarse cereals. The area of chickpea got reduced in favour of wheat.

In spite of the high prices of pigeonpea, profitability of this crop continues to be low due to low yields. The estimates of acreage response functions revealed that the impact of prices on acreage response of pigeonpea has been weak. Unless there are production advances, effects of price are likely to be small in advancing production and profitability.

Table 7. Major dryland crops (1986–87)

Crop	Total area (million ha)	Rainfed area (%)
Wheat	23	33
Rice	42	57
Irrigated	18	—
Lowland	16	38
Upland	6	14
Deep water	2	5
Coarse cereals	40	91
Sorghum	16	95
Pearl millet	11	94
Maize	6	80
Total pulses	23	90
Chickpea	7	80
Pigeonpea	3	96
Total foodgrains	127	68
Total oilseeds	19	81
Groundnut	7	85
Rapeseed & mustard	4	45
Cotton	7	70

SORGHUM: PHENOLOGICAL, PHYSIOLOGICAL AND GENETIC CHANGES

Table 8. All-India compound growth rates of rainfed crops in the Green Revolution era (1967–68 to 1988–89)

Crop	Rate of annual increase (%) in		
	area	production	yield
Rice	0.56	2.60	2.06
Wheat	2.02	5.27	3.17
Coarse cereals	–0.97	0.42	1.34
Sorghum	–0.64	1.23	1.88
Pearl millet	–0.86	–0.04	0.81
Maize	–0.10	0.89	1.00
Finger millet.(Ragi)	–0.02	1.52	1.55
Small millets	–2.60	–2.30	0.31
Total pulses	0.30	0.74	0.51
Chickpea	–0.68	–0.45	0.22
Pigeonpea	1.44	1.96	0.51
Oilseeds			
Groundnut	0.08	1.23	1.14
Rapeseed & mustard	1.50	4.01	2.48
Cotton	–0.35	1.83	2.18

The transformation of the traditional, tall, long duration, and climatically vulnerable tropical sorghums into the relatively short statured, early to medium duration cultivars with stable and economic yields even under the worst droughts encountered, is a fascinating story described elsewhere [5]. All-India average yields from 30-40 yield trials conducted each year over a 10-year period are given in Table 12.

From 1968-69 to 1980-81, the compound rates of sorghum production compared well with irrigated wheat (Table 13). If we consider the kharif sorghum only, the growth rate will be even higher. Later in the 1980s, rate of increase in production was slow because of demand and price

Table 9. Certified seed production of hybrids (1990–91)

Crop	Certificed seed produced (q)	State/quanity of seed (q)
Sorghum	237, 821	Maharashtra (156,646); Karnataka (25,775); Andhra Pradesh (24,200); Madhya Pradesh (22,000); Rajasthan (4,880); Gujarat (2935); Uttar Pradesh (2355); Dadar & N. Haveli (10)
Pearl millet	88,742	Gujarat (49983); Rajasthan (15,743); Maharashtra (12,516); A.P. (2000) Haryana (8500)
Maize	83,188	A.P. (18,300); Karnataka (21,440); Bihar (27,558); M.P. (4750); U.P. (2200); Rajasthan (2943); Sikkim (150) Manipur (300); Orissa (50); Gujarat (690); Maharashtra (1102)
Cotton	44,662	Maharashtra (16,433); Gujarat (15,020); M.P. (2839); Karnataka (1102); A.P. (850)
Castor	16,555	Gujarat (15,735); Maharashtra (616); Rajasthan (50); Karnataka (154)
Major Hybrids:		
	Sorghum	CSH 9 (108, 193); CSH 5 (99,201); CSH 6 (10,732); CSH 1 (9644); CSH 11 (5968)
	Pearl millet	BK 560 (44,468); MH 179 (23,574)
	Maize	Deccan 1 (19,680); High Starch (19,324); GS-2 (15,494); Ganga 5 (13,236)
	Cotton	DCH 32 (12,199); Hy 6 (10,420); Hy 4 (8427)
	Castor	GAUCH 1 (7795); GAUCH 4 (6021)

problems. The kharif sorghum production of Maharashtra doubled during the 1970s. The transformation of kharif sorghum in the black soil belt is "Green Revolution in drylands."

Another significant feature concerning kharif sorghum is the control of shootfly and midge, the two major pests, through management practices only without using pesticides. Sowing with the onset of monsoon and enblock coverages of the area with hybrids to avoid spread of varieties with different maturity periods in a given area were successful preventive measures adopted by farmers. The stability of production has been the result of a phenological adjustment of the growth stages with periods of moisture availability and took care of aberrations during the growth period. There was an optimum adjustment of the total dry matter and its distribution between stalk and grain.

While this approach paid rich dividends against subnormal and drought years in the black soil belt, the problem of occasional late rains during October resulted in greater deterioration and reduced grain quality and prices. The new hybrids like CSH 9 do have some in-built resistance to grain moulds and grain deterioration but if the rains happen to be continuous the soaking and drying of mature grain results in loss of grain quality. However, in such years, there is scope for a second crop of safflower to compensate for the loss due to reduced prices of low quality sorghum grain. The problem of grain moulds deserves further attention.

Table 10. Minimum support prices announced by the Govt. (Rs/q)

Crop	1980–81	1986–87	Increase (%)
Paddy	105	146	39
Wheat	130	166	28
Coarse cereals	105	132	26
Gram	165	280	70
Pigeonpea	190	325	70
Mung	200	325	73
Urd	202	325	63
Groundnut (in shell)	206	315	53
Mustard	250	415	66
Sunflower	183	390	
Cotton (kapas)	304	430 (320F)	116
	—	540 (H4)	

Table 11. Behaviour of wholesale prices of foodgrains from 1970–71 to 1984–85

	Annual increase (%)	CV around trend
Coarse cereals	4.95	15.85
Pulses	8.75	14.06
Rice	6.80	11.67
Wheat	5.22	10.98
All cereals	6.12	12.16
All foodgrains	6.55	10.29

In view of the changing consumption patterns of grain sorghum and increase in fodder prices, a reorientation of objectives has become essential. A beginning has been made in this direction. Future efforts in breeding kharif sorghums should be oriented towards:

(1) Slightly taller height (180–200 cm) without sacrificing grain yield. Studies on optimum plant type (Fig. 10) have shown that this is possible in the 70–75 days flowering duration.

(2) Incorporation of greater levels of resistance to shootfly, midge and grain moulds. Stalk rots and striga also need attention.

(3) The zerazera germplasm has served well in contributing to both yield and grain

Table 12. All-India average yields of promising sorghum hybrids

Year	Yield of different hybrids (q/ha)			
	CSH-1	CSH-5	CSH-6	CSH-9
1976	31.38	35.68	30.90	39.16
1977	30.19	29.52	34.18	37.03
1978	35.82	43.07	42.65	50.36
1979	35.22	38.08	36.48	43.53
1980	30.34	34.37	34.80	38.36
1981	34.48	42.78	36.32	43.49
1982	32.88	34.91	34.98	41.39
1983	28.29	31.30	29.01	36.91
1984	28.87	34.34	33.80	41.28
1985	32.34	34.07	32.73	38.89
Mean	31.97	35.81	34.59	41.04

quality. There are indications of zerazera derived males, females and varieties stagnating for yield. A wider germplasm needs to be utilized to get over these yield plateauing tendencies.

(4) Utilization of diverse cytoplasms which have been identified and well characterized. Apomixis, discovered in India, is yet to be used in fixing heterosis and efforts need to be strengthened.

(5) Enhancement of utility base of kharif sorghums through use in cattle and poultry feeds, production of industrial starches, high fructose syrup, malt and malt based foods and brews, energy, gur etc., oriented towards whole plant utilization (Fig. 11).

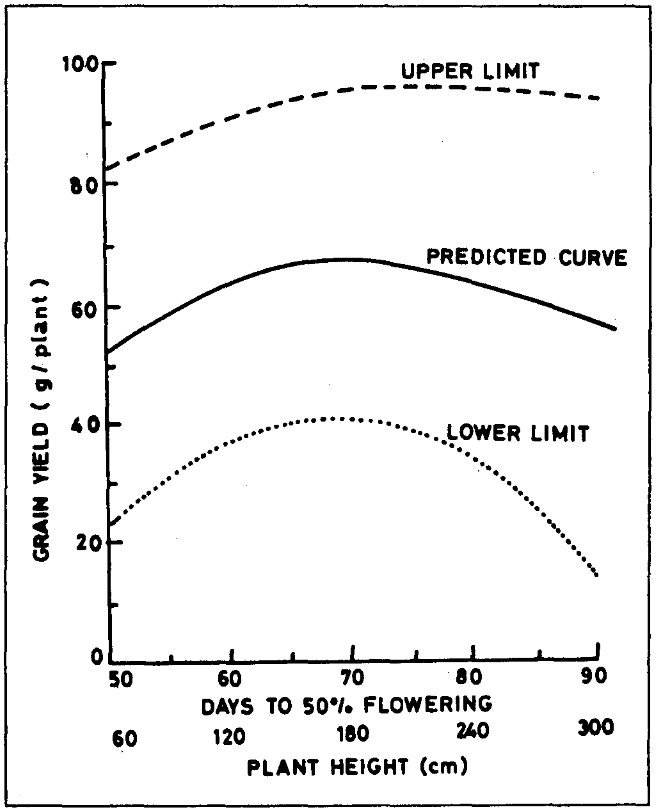

Fig. 10. Optimum phenotype as related to plant height and days to flowering.

(6) The rabi sorghum production has been stagnating. Exploitation of rabi germplasm in developing males, females, and hybrids to overcome the problem of low temperature sensitivity and shoot fly susceptibility of kharif based males and females is required and there are indications of progress in this direction. Improvement of quality rabi sorghum for human consumption is an urgent need.

Table 13. Compound growth rates of sorghum compared to other cereals on all India basis (1968-69 to 1980-81)

Crop	Area (%)	Production (%)	Yield (%)
Rice	0.73	2.20	1.45
Wheat	2.92	5.65	2.64
Sorghum	−1.18	2.06	3.28
Pearl millet	−1.16	−0.34	0.79

The sorghum improvement programmes now need a different orientation to meet the changing consumption and price trends and should provide the basis for agro-industrial development of the black soil kharif sorghum belt.

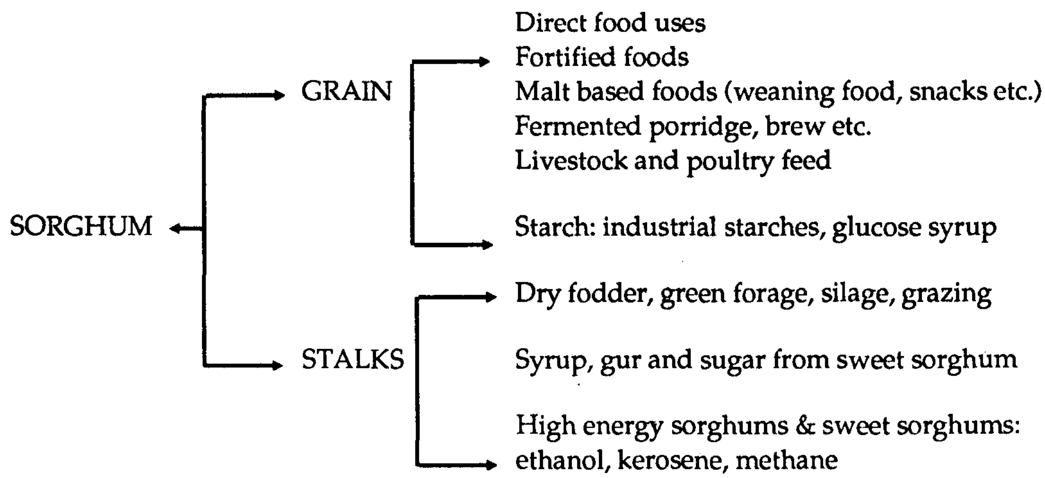

Fig. 11. Whole plant utilization of Sorghum.

PEARL MILLET

The introduction of hybrid pearlmillet in the mid-1960s witnessed rapid growth in its production, but the susceptibility of the hybrids to downy mildew proved to be a major setback. Subsequent efforts in developing new hybrids and populations salvaged the problem to a great extent, but on account of the soil-climatic conditions, the northwestern arid zone, the predominant pearlmillet belt, is inherently vulnerable. This region probably could resort to alley cropping of pearlmillet with perennials. Research on durable resistance of pearlmillet to downy mildew needs strengthening.

COTTON: GAINS AND PROBLEMS OF SPECIES CHANGE

At the time of independence, 97% of the cotton cultivated in the country belonged to the diploid desi type (*G. arboreum*, 65%); and tetraploid American cotton (*G. hirsutum*) constituted only 3%. The tetraploids, both varieties and hybrids, now cover 63% of total cotton area (Table 14). The shift was a result of the policy of meeting the needs of our long staple cotton and avoid imports. Apart from the staple consideration, the shift from desi to American cotton was prompted by:

(1) The realization that potential for high yield did not exist in desi cotton

Table 14. Species composition of cotton in India over different periods

Species	Area in thousand hectares					
	Pre-War	Independence	1955–56	1960–61	1965–66	1989–90
G. hirsutum	150 (2)	140 (3)	1630 (20)	2200 (29)	3210 (41)	3140 (41.6)
G. barbadense	Nil	Nil	Nil	4	8	10
G. arboreum	5210 (64)	2790 (65)	4400 (54)	3450 (45)	2840 (36)	1320 (17.5)
G. herbaceum	2710 (34)	1390 (32)	2050 (25)	2030 (26)	1780 (23)	950 (12.6)
Hybrid	Nil	Nil	Nil	Nil	Nil	2130 (28.2)

Figures in parentheses indicate percent of total area.

(2) That desi cotton does not respond to irrigation and hence a total shift to the American cotton under irrigation

(3) The advent of pyrethroids for boll worm control

(4) The advent of intra-hirsutum and inter-specific cotton hybrids

(5) The variety and staple oriented price policy favourable to American cotton varieties and hybrids

The consequences of the shift from desi to American cotton varieties and hybrids have been:

(1) Cotton production has gone up primarily because of increased irrigation.

(2) Long staple requirements were largely met saving foreign exchange.

(3) Large increase in the use of pesticides on tetraploid cottons: 55% of the total insecticides are consumed in cotton in India.

(4) Pest resurgence and pest resistance, mainly whitefly and *Heliothes*.

(5) Constant instability and fluctuations in cotton production.

(6) Desi cotton varieties were pushed to less favourable areas, and less effort on desi cotton improvement.

The desi cotton varieties established their superiority in critical comparative trials of improved desi and American varieties, and hybrids in Marathwada/Maharashtra for yield under rainfed and irrigated conditions (Tables 15, 16), under different dates of planting (Table 17), and under irrigation and fertilization (Table 18). Irrigation responses were

Table 15. Average seed cotton yield (kg/ha) in desi, American cotton varieties and hybrids over years and locations under rainfed condition

Year	No. of trials	Mean yield (kg/ha)			Increase (%) of desi over	
		desi	Am. vars.	hybrids	Am. vars.	hybrids
1985–86	10	1946	1293	1442	50.5	35.0
1986–87	15	1701	1065	1278	59.7	33.0
1987–88	20	2045	1458	1608	40.2	27.1
Mean	(45)	1897	1272	1443	49.0	31.4

however low, with the exception of hybrids (Table 18). Under limited and recommended plant protection (Table 19), the desi cotton varieties were superior to American cottons. Pest resurgence on desi cotton was much less compared to the American varieties and hybrids (Table 20). Under all management conditions, the desi varieties proved their superiority.

The fibre properties of some of the improved desi (*G. arboreum*) cotton varieties are compared with the American (*G. hirsutum*) and Egyptian cottons (*G. barbadense*) in Tables 21, 22. The fibre length and ginning outturn of new desi varieties are comparable to those of American cotton varieties and hybrids. The micronaire values are high. If they are brought to the level of American cottons, the desi varieties are likely to spin much better and this aspect should form the primary objective in future cotton breeding.

Table 16. Mean seed cotton yield in Marathwada

Species	Variety/ hybrid	Yield of kapas (kg/ha)	
		irrigated (3 locations)	rainfed (7 locations)
G. hirsutum	SRT 1	1929	747
	Purnima	1559	695
	Mean	1694	721
G. hirsutum (short statured)	PKV 081	2189	856
	NH 262	1931	771
	Mean	2060	814
Hybrid (intra-*hirsutum*)	NHH 44	2086	670
Hybrid *G. hirsutum* x *G. barbadense*	DCH 32	1784	553
G. arboreum	Rohini	2931	983
	Eknath	2904	890
	Mean	2918	937

Table 17. Varietal response to dates of sowing in cotton at Nanded (rainfed)

Species/hybrid	Yield of seed cotton (kg/ha)			
	June 21	July 11	July 31	August 20
G. arboreum	2319	2299	2014	672
G. hirsutum	1358	963	702	419
G. hirsutum (short statured)	1429	1002	764	393
Intra-specific hybrids of *G. hirsutum*	1505	1360	809	301

The desi varieties have also shown considerable variability for plant type, boll size, boll number, length of fruiting branches etc., and could be incorporated into improved cultivars [6].

Table 18. Varietal response in cotton to fertilizer and irrigation applications (1986–87 to 1988–89)

Species/hybrid	N:P:K	Yield of seed cotton (kg/ha)		
		no irrigation	irrigation 125 CPE	irrigation 250 CPE
G. arboreum	50:25:25	2323	2891	2475
	100:50:50	2463	3237	2595
G. hirsutum	50:25:25	1744	1832	1542
	100:50:50	2199	2144	2130
G. hirsutum	50:25:25	1568	1909	1738
(short statured)	100:50:50	2258	2456	2080
Intra-*hirsutum*	50:25:25	1604	2233	1948
hybrids	100:50:50	2326	2872	2479

Cotton is the single crop which is consuming 55% of the total pesticides used in the country, which also posed problems of pest resistance and resurgence. The demand for long and extra long staple being almost fully met, medium and superior medium staples are the need of the country.

An appropriate cotton policy, which should include pricing of desi cottons, which are currently low as compared to the American cotton varieties, would meet the needs of the country, promote dryland agriculture, and reduce problems of pesticide use and pest resistance and resurgence.

Table 19. Varietal response in cotton to plant protection at Nanded (rainfed)

Species/ hybrid	Seed cotton yield (kg/ha)	
	limited plan protection	full plant protection
G. arboreum	1708	2205
G. hirsutum	712	1041
G. hirsutum (short statured)	737	1125
Intra-*hirsutum* hybrids	721	1295

I should not be misunderstood as criticising the policy of promoting American cotton, which is needed to meet our staple requirements and save foreign exchange.

Having met this objective, now it is necessary to establish a balance between desi and American cottons in the irrigated and rainfed sectors in such a way that they meet the current and future staple needs and export requirements, at the same time minimising the ecological problems arising from excessive pesticide use.

PULSES AND OILSEEDS: COMPONENTS OF DRYLAND CROPPING SYSTEMS

Both demand and price situation are favourable to oilseeds and pulses but productivity advances under rainfed conditions continue to be low. High prices, therefore, do not have a long term effect on production.

The rainfed belt of India is predominated by coarse cereals like sorghum, pearl millet, rainfed maize, ragi etc., rainfed wheat and upland rice. There is need for diversification of the range of commodities and crops in this belt. To me, more than stepping up inherent yield potentials of oilseeds and pulses, the work on which, no doubt, should continue, pulses and oilseeds should find an increasing proportion both in inter- and multiple cropping systems.

While delivering the Vasanta Rao Naik memorial lecture, I made a detailed analysis of production and production stability of various crops in Maharashtra during the 1980s. These studies revealed that:

Table 20. Resurgence of whitefly under boll worm control in cotton (1986–87)

Variety/hybrid	Plant protection cover	White flies per leaf	
		limited plant protection	full plant protection
***G. arboreum*:**	0 + 3		
Rohini		1.27	0.98
Eknath		0.98	1.07
***G. hirsutum*:**	3 + 4		
Purnima		5.19	7.37
SRT-1		5.52	7.35
PVK 081 (short statured)		5.07	8.20
NH 262 (short statured)		5.72	8.09
Intra-*hirsutum* hybrids:	3 + 4		
H-4		5.86	8.49
Godavari		8.82	9.83

Table 21. Fibre properties of different cotton varieties and hybrids

Species/hybrid	Variety or hybrid	GOT (%)	MFL (mm)	MIC	MAT coefficient	PSI
G. hirsutum	SRT 1	37.8	23.9	3.8	0.71	8.2
	Purnima	37.1	23.4	3.7	0.69	8.0
G. hirsutum (dwarf)	PKV 081	36.2	22.9	4.0	0.73	7.5
	NH 262	36.6	23.1	3.8	0.71	8.5
Hybrid (intra-*hirsutum*)	NHH 44	35.5	22.9	3.1	0.64	7.8
Hybrid (*G. hirsutum* x *G. barbadense*)	DCH 32	34.1	30.5	2.8	0.53	9.4
G. arboreum	Rohini	37.4	23.9	5.1	0.83	8.5
	Eknath	38.5	22.9	5.8	0.83	8.7

(1) Kharif sorghum and rabi safflower, both rainfed, are the most stable crops, followed by pigeonpea. Safflower responds well even to a single irrigation if water is available. Rainfed cropping systems should, therefore, be designed around these crops.

(2) Of the unstable production systems, cotton during kharif, sorghum during rabi, and sunflower both under rainfed and irrigated conditions proved to be most unstable. Kharif groundnut was also unstable in production.

(3) Sugarcane was most stable among the irrigated crops. The areas planted under

irrigated wheat and summer groundnut exhibited wide fluctuations. While yields of irrigated wheat were stable, the productivity of summer groundnut fluctuated due to uncertain water supplies.

Table 22. Fibre characters of twelve gaorani (*G. arboreum*) selections as compared to *G. hirsutum* and *G. barbadense* strains

Selection No.	Fibre length 2.5% span length (mm)	(inch)	Pressley strength index lb/mg	Species
10	29.5	1.16	9.1	*G. arboreum* race *indicum*
11	30.2	1.19	9.2	"
12	30.0	1.18	9.4	"
13	30.0	1.18	9.2	"
14	30.2	1.19	9.2	"
15	31.8	1.25	9.0	"
19	29.0	1.14	9.8	"
26	29.5	1.16	9.8	"
45	30.2	1.19	9.4	"
54	30.2	1.19	9.7	"
102	30.7	1.21	10.1	"
153	30.0	1.18	9.4	"
Sujata	32.8	1.29	8.5	*G. barbadense*
Sea island (Andrews)	29.0	1.14	8.2	"
Hybrid 4	29.0	1.14	8.4	*G. hirsutum*
M.C.U. 5	29.0	1.14	7.7	"

Source. M. R. H. Qureshi and N. G. P. Rao [6].

(4) These studies, therefore, pointed out that intercropping systems based on kharif sorghum, with increasing proportion of pigeonpea, groundnut, and soybean are likely to be more profitable and meet the needs of the region and people with respect to food, protein, oil and fodder, and could be optimized for profit. The groundnut-soybean or groundnut-pigeon-pea systems are other alternatives.

(5) Safflower has tremendous potential for expansion during rabi in the risky areas of rabi sorghum and as a second crop in the assured rainfall belt of Marathwada, Vidarbha, Malwa plateau and assured rainfall districts of Rajasthan. Safflower comes up well in the black soil regions of M.P. and could be considered as a possible substitute to rainfed wheat. The farmers need to be educated on its cultivation, harvesting and the value of its oil.

(6) The entire groundnut area of black soils of Gujarat can be intercropped with early duration pigeonpea or soybean.

(7) Cotton hybrids, both under irrigated and rainfed conditions, are cultivated in widely spaced rows. Soybean, urd, pigeonpea etc., are the possible intercrops for cotton in the black soil belt.

(8) Incorporation of greater levels of resistance to mosaic will enable mung, urd and early soybean to pervade in vast areas in kharif in the North Indian plains and as a

catch crop in several irrigated situations. The additional opportunities for mung and urd in rice fallows and various other situations need to be further exploited.

(9) Soybean cultivation as a sole crop has vast potential in the assured rainfall situations of kharif in several states and could become an important instrument in diversification of crops in the areas of better rainfall, and could provide sound agro-industrial base.

Table 23. Variability for plant type in gaorani cotton (*G. arboreum*)

Character		Short statured variant	Gaorani 6 (control)
Plant height (cm)	mean	78.4	130
	range	63-92	130-160
Internodal length (cm)	mean	3.2	4.7
	range	2.4-3.6	3.3-5.5
Bolls/plant	mean	18	12
	range	14-26	5-15
Maximum No. of bolls per fruiting branch		4.0	2.0
Mean length of fruiting branches (cm)		9.0	4.0
Days to maturity		130-150	200

Source. M. R. H. Qureshi and N. G. P. Rao [6].

Note. The comparative studies reported above on *G. arboreum*, *G. hirsutum* and hybrids were planned when I was working as the Vice-Chancellor of the Marathwada Agricultural University and conducted by my colleagues, which I respectfully acknowledge.

Our earlier studies on competition of species and stability of sole and intercropping systems [7] have brought out pigeonpea and soybean as important components. The sorghum based cropping systems are most stable and out of them sorghum–pigeonpea and sorghum–soybean were superior. Amongst the groundnut-based cropping systems, groundnut–pigeonpea was most stable. Groundnut–sorghum and groundnut–soybean combinations, though not very stable, are productive and could compen- sate for the pro- duction risks of kharif ground- nut. A summ- ary of these studies are presented in Table 24.

Based on several sor- ghum based intercropping studies in India, Rao and Rana [8] estimated the projected area under intercropping for additional acreages under

Table 24. Stability parameters for total yield in intercropping systems

Intercrop	Sorghum			Intercrop	Groundnut		
	yield (q/ha)	regression coefficient	deviations		yield (q/ha)	regression coefficient	deviations
Pigeonpea	56.85	0.92	NS	Sorghum	38.77	2.11**	**
Castor	39.57	1.00	NS	Pigeonpea	23.15	0.89	NS
Groundnut	50.53	0.99	NS	Castor	16.54	0.51**	*
Soybean	55.53	1.03	NS	Soybean	17.34	0.49**	**
Mean	53.58				23.95		
SE	61.9				31.1	0.11	

*,**Significant at 5% and 1% levels, respectively; NS—nonsignificant.

pulses and oilseeds to meet shortages. These are reproduced in Table 25.

Table 25. Production potential of oilseeds and pulses in sorghum-based intercropping systems (kharif 1972–78)

Intercrop	No. of experi-ments	Average yield (q/ha)				Projected area in million ha for 1 million ton production at		
		sorghum (sole crop)	intercrop (sole crop)	sorghum (in inter-cropping system)	intercrop (in inter-cropping system)	minimum yield potential	average yield potential	maximum yield potential
Oilseed crops:								
Groundnut	57	33.6	10.4*	33.1	4.8	2.60	2.08	1.73
Castor	20	36.7	20.2*	32.9	5.3	2.78	1.90	1.44
Sunflower	10	33.6	16.1	21.7	3.4	8.00	2.99	1.84
Pulse crops:								
Pigeonpea	115	35.8	16.5	32.4	9.4	1.16	1.07	1.00
Soybean	60	33.0	13.9	32.2	5.5	2.08	1.82	1.61
Mung	38	33.5	8.2	33.7	3.0	3.90	3.25	2.78
Urd	30	40.9	9.5*	33.8	2.8	4.58	3.55	2.90
Cowpea	21	43.5	8.2*	38.1	2.7	5.75	3.67	2.69

*Data based on less number of experiments.

The vast amount of data obtained in the country under various projects on different crops and cropping systems, both under inter- and sequence cropping, has not been put to practical use. It is time to give serious consideration and arrive at policy decisions and their implementation on cropping systems.

LOCATION SPECIFICITY AND WIDER ADAPTATION

The lack of progress in dryland agriculture has often been attributed to lack of location specificity in research and developmental efforts.

If we look back to the All-India Coordinated Research Projects, the high yielding varieties of wheat like Kalyan Sona, Sonalika and several HD varieties, the IR rice varieties, the sorghum and pearl millet hybrids were all widely adapted and were the result of testing under diverse agro-climatic conditions both in space (locations) and time (years). Even maize hybrids, which were released zonally to begin with, have now shown wider adaptation. Subsequently, most crop improvement programmes got zonalised with the purpose of meeting regional needs and imparting locational specificity. This approach has naturally resulted in limiting test environments. Even though the number of varieties released have increased, the widely adapted varieties of yesteryears have stood the test of time.

Recently, I made a detailed analysis of the zone x genotype interactions in case of several crops and estimated the proportion of variability accounted by the zone x genotype interaction. The common data sets were limited, yet the results were convincing that the proportion of variability due to zone x genotype interaction accounted for a very small fraction of the total variability.

A recent analysis of the performance and stability of improved rice cultivars revealed that there were no restrictions to adaptability within an ecosystem. Evenson's contention that adaptability and stability are different and if so the rice programmes on varietal development may need a different orientation did not come true.

Adaptability and stability were well correlated and the large location-dependent fluctuations in yield were more due to the production environment and not due to genotypic causes. Locational-dependent specificity is certainly important in developing the cultivation practices, cropping systems, and management norms for the production environment. It became clear that varietal development under wider testing would enable selection of more plastic (adapted) varieties with better buffering and broad based resistance to a range of biotic and abiotic stresses.

If this was so with rice, it is even more relevant for rainfed crops where production is more prone to climatic fluctuations. This has been amply demonstrated in case of sorghum and pearl millet hybrids. I shall illustrate this with some data from sorghum presented in Table 26 and Fig. 12.

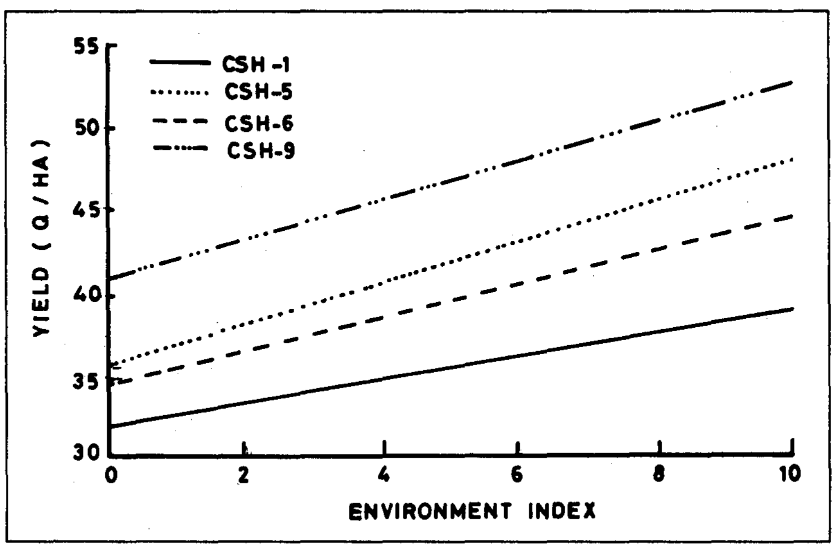

Fig. 12. Yield-environment relationship of sorghum hybrids.

The improved hybrids are superior in all environments. This is further illustrated by the data presented in Table 27, which shows that the really superior genotypes are superior under both low and high management regimes (Table 28). The sorghum work has also proved that compared to improved varieties, hybrids have better buffering capacity against environmental fluctuations as revealed for genotypes and their interactions with environment (Table 28).

Table 26. Stability parameters of sorghum hybrids over years and places (1976–85)

Hybrid	Mean yield (q/ha)	Regression coefficient (b)	Deviation MS
CSH-1	31.97	0.69**	1.459
CSH-6	34.59	0.97**	2.520
CSH-5	35.81	1.20**	2.744
CSH-9	41.04	1.14**	1.147

**Significant at 1% level.

I shall further illustrate this with maize which started with a zonal approach. Tables 29 and 30 provide means and analysis of variance for four diverse check varieties across zones. The zone x genotype component accounted for only a small fraction of the total variability. Maize has now moved towards release of hybrid cultivars on a wider regional basis. The same is true of several other crops.

The wider testing across zones (barring totally different ecosystems like hills, deep water systems, salinity–alkalinity situations etc.) enabled identification of larger genotypic differences, eliminated more sensitive types and favoured genotypes that could stand a range of fluctuating agro-climatic factors. Wide adaptation, adaptability and high yield are not certainly negatively correlated and more stable high yielding genotypes could be identified. This is not to be misunderstood as pleading for one variety for all areas or adaptability for all conditions. The point is that the genotype x environment interactions

Table 27. Mean yield and ranks of some hybrids and varieties under high and low management during kharif seasons of 1974, 1975 and 1977

Hybrid or variety	High management yield (q/ha)	High management rank	Low management yield (q/ha)	Low management rank
Hybrids:				
CSH-1	35.69	4	24.68	4
CSH-5	45.14	1	31.85	2
CSH-6	41.25	3	33.46	1
Varieties:				
CSV-3	32.00	5	19.70	5
CSV-5	26.22	6	17.01	6

Table 28. Estimates of components of variance for grain and fodder yield of kharif sorghum varieties and hybrids

Component of variance	Grain yield varieties	Grain yield hybrids	Fodder yield varieties	Fodder yield hybrids
σ^2_g	20.03	11.22	422.42	487.35
σ^2_{gl}	10.45	4.25	242.71	59.97
σ^2_{gy}	–0.83	0.40	19.61	–5.32
σ^2_{gly}	27.57	21.30	503.02	255.03
σ^2_l	8.36	9.57	120.24	128.74

Table 29. Three years average yields of maize checks in different zones (1983–85)

Zone	Yield (q/ha)				Mean
	J-684	Ganga-5	Agenthi-76	Tarun	
Zone 1	43.9	44.9	44.4	40.5	43.4
Zone 2	39.2	35.3	36.4	31.0	35.5
Zone 3	32.3	34.6	35.3	31.2	33.4
Zone 4	34.0	38.2	36.4	28.8	34.4
Zone 5	26.1	24.8	26.3	23.9	25.3

Table 30. Pooled analysis for three years (1984-1986) of the grain yield of maize (q/ha)

Source	d.f.	Variation (%)
Years (Y)	2	3.70
Zones (Z)	4	44.74
Genotypes (G)	3	4.90
Z x Y	8	3.60
Z x G	12	2.60
Y x G	6	0.56
Y x G x Z	24	39.85

should be understood well by organising the testing programmes across diverse situations and based on data appropriate release recommendations could be made.

The immediate production environment would provide the base for the development of manage- ment practices and cropp- ing systems, and should account largely for the location specificity. The need is for a synthesis and balance between varietal testing, wide adaptation and area specifics.

In conclusion, I would like to plead that certain aspects of dryland agriculture have witnessed dynamic changes in their varietal composition and resource management perceptions. They contributed prominently to yield advances, though not to the extent desired. The time is ripe to charter our coarse for future. This is an analysis in that direction. The future is optimistic.

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