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Impacts of Improved Sorghum Cultivars in India

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Introduction

Sorghum (*Sorghum bicolor*) is the third most important cereal crop in India after rice and wheat. During 1995-98, it was grown over 11.2 million hectares with a total production of 9.4 million tons (CMIE 2000). Though the area under sorghum in India has declined over time, production has remained more or less constant due to increase in yield. During 1995-98, Maharashtra ranked first in terms of area under sorghum and its production (Table 1), followed by Karnataka, Madhya Pradesh and Andhra Pradesh.

Indian farmers have plenty of experience in growing improved sorghum cultivars. In fact, the first sorghum hybrid, CSH 1, was released in India in 1964. By 1998-99, 71% of the total sorghum area was under improved cultivars. More than 180 improved sorghum cultivars are now available for cultivation. Often, public and private research institutes in India have developed these cultivars in partnership with ICRISAT. Improved cultivars, particularly rainy-season hybrids, have many desirable traits such as higher productivity, wider adaptability, short duration, and stature (Rao and Rana 1982).

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Table 1. Trends in sorghum area, production, and yield in India, 1970-98.

State	1970-75	1980-85	1990-95	1995-98
Area ('000 ha)				
Andhra Pradesh	2646	2045	1066	833
Gujarat	1088	930	506	319
Haryana	188	135	111	129
Karnataka	2225	2122	2160	1959
Madhya Pradesh	2102	2135	1368	940
Maharashtra	5821	6553	5851	5583
Rajasthan	1003	949	751	592
Tamil Nadu	692	658	511	436
Uttar Pradesh	701	646	476	419
India	16514	16231	12796	11247
Production ('000 t)				
Andhra Pradesh	1240	1256	776	609
Gujarat	389	543	275	258
Haryana	50	34	39	30
Karnataka	1724	1639	1701	1747
Madhya Pradesh	1475	1715	1214	796
Maharashtra	2251	4690	5317	4987
Rajasthan	368	422	304	233
Tamil Nadu	515	493	543	360
Uttar Pradesh	425	481	427	373
India	8461	11313	10593	9414
Yield (kg ha^{-1})				
Andhra Pradesh	469	614	728	731
Gujarat	357	584	543	807
Haryana	266	255	353	233
Karnataka	775	772	787	892
Madhya Pradesh	702	803	887	847
Maharashtra	387	716	909	893
Rajasthan	366	444	405	392
Tamil Nadu	743	750	1063	825
Uttar Pradesh	606	744	897	889
India	512	697	828	837

Source: CMIE (2000).

This study quantifies the impacts of improved sorghum cultivars in India, measured in terms of yield gain, reduction in cost of production and yield stability.

Data and Research Methodology

Data

The study used data collected from three sources: district-level secondary data published in the State Season and Crop Reports and Statistical Abstracts, rapid appraisal techniques, and cost of cultivation data published by the Ministry of Agriculture (1996). District-level yield data for 1966-94 covering 146 sorghum-growing districts in seven states — Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Rajasthan, and Tamil Nadu — were used to estimate yield and stability gains. Together, these districts accounted for about 96% of the total sorghum area and 95% of sorghum production in India (1991-94 average). Data on area under specific varieties of sorghum were collected and validated using rapid appraisal and Delphi techniques. Data on improved cultivars gathered from crop statistics published for different states were complemented by elicitation/validation from experts. The experts comprised specialists in research institutions, private seed companies, state seed certification agencies, the National Seeds Development Corporation, state seed development corporations, directorates of agriculture, Training and Visit (T&V) Offices, and seed dealers. Reduction in cost of production was estimated using cost of cultivation data published by the Government of India.

Analytical Procedure

The adoption of improved sorghum cultivars was measured as a percentage of improved to total sorghum area. Yield gain was measured by calculating the increase in average yield levels in 1992-94 over those in 1966-68 for rainy- and postrainy-season sorghum separately. An analysis of yield and instability in sorghum yield was undertaken for two periods — 1966-67 to 1980-81 and 1981-82 to 1993-94. Yield instability was measured using the Cuddy-Della Valle index. The simple coefficient of variation (CV) overestimates the level of instability in time-series data characterized by long-term trends while the Cuddy-Della Valle index corrects the coefficient of variation by:

$$CV = (CV^*)\ (1 - R^2)^{0.5} \qquad \ldots(1)$$

where,
CV is the Cuddy-Della Valle index, i.e., corrected coefficient of variation referred to either as CV or instability index, CV* is the simple estimate of CV (in %), and R^2 is the coefficient of determination from time-trend regression adjusted by the number of degrees of freedom.

To test the differences in CV between the two time periods, Z* statistics was computed[3].

$$Z^* = (CV_2 - CV_1) \{[(1 + 2c^2)/2](1/n_1 - 1/n_2)\}^{0.5}/c \qquad \ldots(2)$$

where, CV_2 and CV_1 are the CV of periods 2 and 1, respectively
n_1 and n_2 are the number of years during periods 1 and 2, and c is the CV in period 1.

The change in CV for each district was tested using the Central Limit Theorem to compute $Z^* = SZ_i/m^{0.5}$, where Z_i are the standard normal test statistics for each observation of Equation (2) and m is the number of observations in the sample.

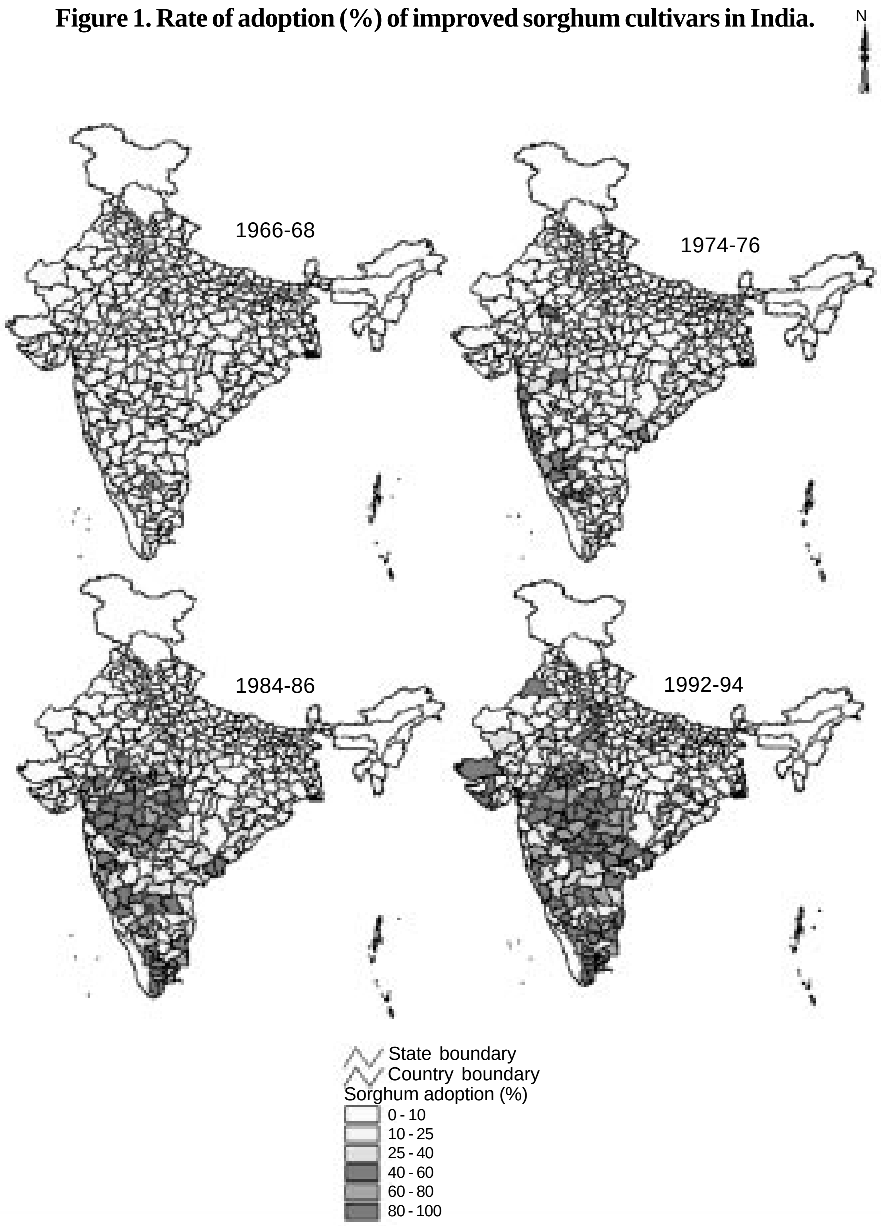
Results and Discussion

Adoption of Improved Sorghum Cultivars

The level of adoption of improved sorghum cultivars in different districts of India for four periods (1966-68, 1974-76, 1984-86, and 1992-94) is shown in Figure 1. A rapid rate of adoption was observed in Tamil Nadu and Maharashtra states while it was very slow in Rajasthan and Gujarat. The rate of adoption was higher (more than 80%) in most districts of Maharashtra and in some districts of Andhra Pradesh. In 1992-94, farmers in 28 districts — Nanded, Jalgaon, Nagpur, Yeotmal, Akola, Amravati, Wardha, Kolhapur, Buldhana, Sangli, Nasik, Osmanabad, and Dhulia (Maharashtra); Indore, Dhar, Betul, and Morena (Madhya Pradesh); Aligarh, Allahabad, and Buduan (Uttar Pradesh); East Godavari, Khammam, and Karimnagar (Andhra Pradesh); Shimoga and Hassan (Karnataka); Ganganagar (Rajasthan); Tirunelveli Kattabomman (Tamil Nadu); and Rajkot (Gujarat) — adopted improved cultivars in more than 80% of the

[3] For details see Kendall and Stewart (1969); Anderson and Hazell (1989).

Figure 1. Rate of adoption (%) of improved sorghum cultivars in India.



sorghum area. Sixteen other districts — Beed, Chandrapur, and Parbhani (Maharashtra); Shivpuri, Khargone, Sehore, Raisen, Chindwara, Khandwa, Shajapur, and Narsimhapur (Madhya Pradesh); Cuddapah (Andhra Pradesh); Chikmagalur and Bellary (Karnataka); North Arcot (Tamil Nadu); and Bulandshar (Uttar Pradesh) — showed adoption levels ranging between 70 and 80%. Trends in the adoption of different improved sorghum cultivars in India are shown in Table 2. The initial rapid adoption of CSH 1 is evident, as is the subsequent adoption of CSH 5, CSH 6, and CSH 9. MSH 51, a cultivar from the private sector and popularly known as Mahyco 51, was widely adopted by farmers. JKSH 22, another cultivar from the private sector, is also gaining ground. Improved varieties were always less popular than hybrids (Rana et al. 1997). Since hybrids provide higher yield and are readily available from a large number of private and public seed companies, their adoption took off easily. Three phases were observed in the spread of improved sorghum cultivars in India. The first phase continued up to 1975 when only CSH 1 was the improved cultivar. During this period, CSH 1 mainly replaced traditional local cultivars. The second phase was between 1976 and 1986 when the major improved cultivars were CSH 5 and CSH 6. This phase was characterized by the replacement of traditional and

Table 2. Trends in adoption of improved sorghum cultivars in India, 1966-98.

	Adoption (% of total sorghum area)							
Cultivar	**1966**	**1971**	**1976**	**1981**	**1986**	**1991**	**1996**	**1998**
CSH 1	1.06	4.14	6.14	0.00	0.00	0.00	0.00	0.00
CSH 5	0.00	0.00	9.21	11.69	13.79	0.00	0.00	0.00
CSH 6	0.00	0.00	0.00	11.69	13.79	0.00	0.00	0.00
CSH 9	0.00	0.00	0.00	0.00	6.90	43.86	20.00	12.00
CSH 13	0.00	0.00	0.00	0.00	0.00	0.00	12.00	15.00
CSH 14	0.00	0.00	0.00	0.00	0.00	0.00	13.00	16.00
MSH 51	0.00	0.00	0.00	0.00	0.00	8.22	14.00	15.00
JKSH 22	0.00	0.00	0.00	0.00	0.00	0.00	6.00	8.00
Other improved cultivars	0.00	0.00	0.00	0.00	0.00	2.74	5.00	5.00
All improved cultivars	1.06	4.14	15.35	23.38	34.48	54.82	70.00	71.00

Source: Estimates are based on rapid appraisal.

initial improved cultivars (CSH 1, CSH 2 and CSH 4) with new ones (CSH 5 and CSH 6). The third phase began after 1986 when the initial cultivars were replaced by new ones (CSH 9, MSH 51, JKSH 22, CSH 13, and CSH 14) at a faster rate. During this period, Indian farmers began to get acquainted with a large number of private sector hybrids in the market.

Average Yield and Yield Gain

Figure 2 shows average rainy-season sorghum yield and yield gains in 1992-94 compared to 1966-68, in different districts of India. Grain yield gains in Maharashtra and Andhra Pradesh were high where adoption rates too were high. The increase in yield was at least 750 kg ha^{-1} in these districts and more than one ton in many others. The yield increase per hectare was more than one metric ton in the districts of Dhulia, Parbhani, Jalgaon, Kolhapur, Nasik, Akola, and Buldhana (Maharashtra); Anantapur (Andhra Pradesh); Shimoga (Karnataka), and Bharuch (Gujarat). Almost all these districts reported more than 80% adoption levels. Yield increased by more than 750 kg ha^{-1} in Ahmednagar, Satara, Pune, Amravati, Osmanabad, Aurangabad, and Nanded districts. Yield doubled in these districts. Yield either doubled or increased by more than 80% in other high-adoption (>80%) districts such as Nagpur and Yeotmal (Maharashtra); Khammam, East Godavari, and Karimnagar (Andhra Pradesh); Allahabad and Buduan (Uttar Pradesh); and Rajkot (Gujarat). A majority of the districts in Andhra Pradesh experienced more than 80% yield gain.

Figure 3 depicts average postrainy-season sorghum yield and yield gains. Increase in grain yield was less during the postrainy season than during the rainy season. Increase in yield was greater than 500 kg ha^{-1} in only four districts (Kolhapur and Jalgaon in Maharashtra, Kurnool in Andhra Pradesh, and Chikmagalur in Karnataka). Postrainy-season sorghum yield in these districts in 1992-94 was more than double that of 1966-68. Yield increased by more than 100% in Anantapur, Mahabubnagar, and East Godavari districts of Andhra Pradesh. In some districts of Maharashtra (Nagpur, Wardha, Osmanabad, Satara, and Ahmednagar), and Karnataka (Chitradurga and Bidar), there was a slight decrease in yield, whose cause needs to be researched. Yields increased in the other districts of Maharashtra, Karnataka, and Andhra Pradesh where private and public seed companies were active and some postrainy-season sorghum hybrids were cultivated.

Figure 2. Average rainy-season sorghum yield and yield gain in India.

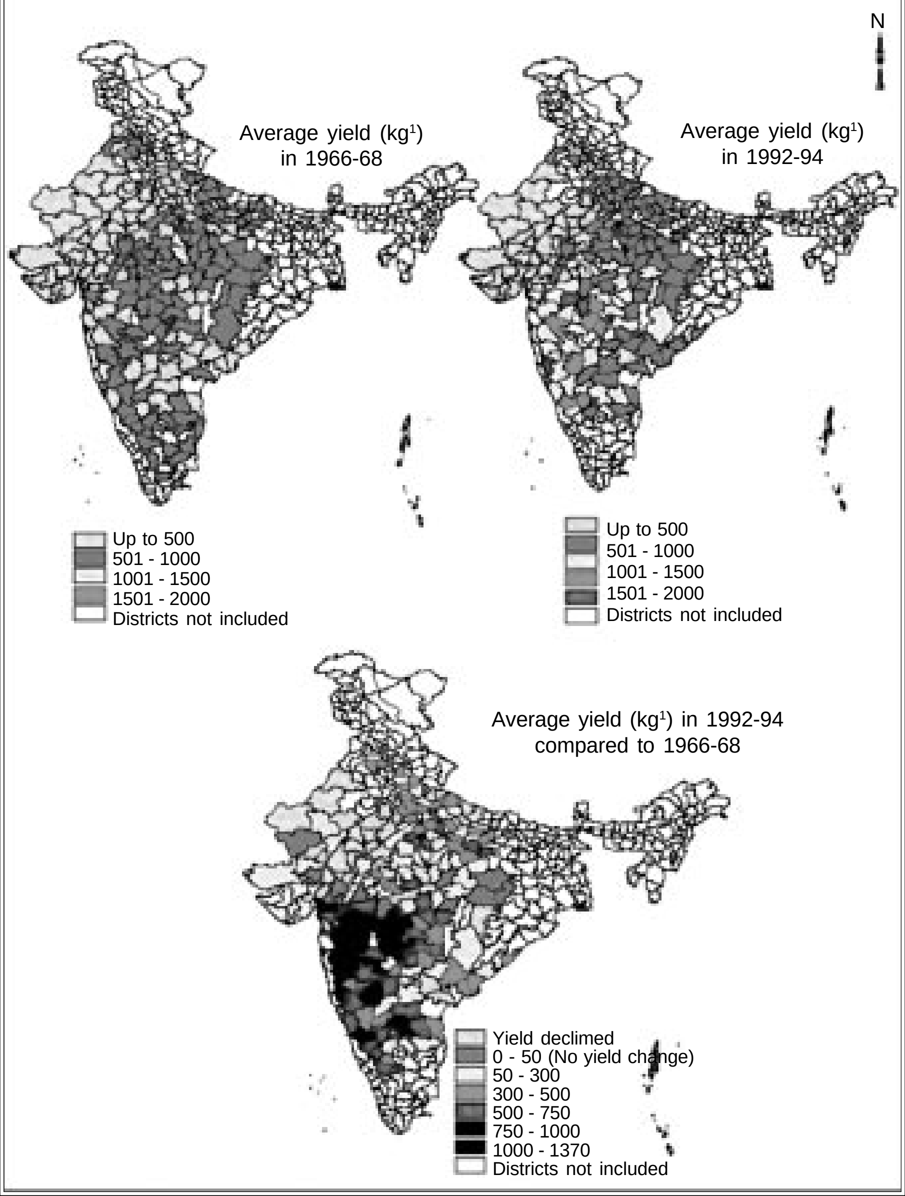


Figure 3. Average postrainy-season sorghum yield and yield gain in India.

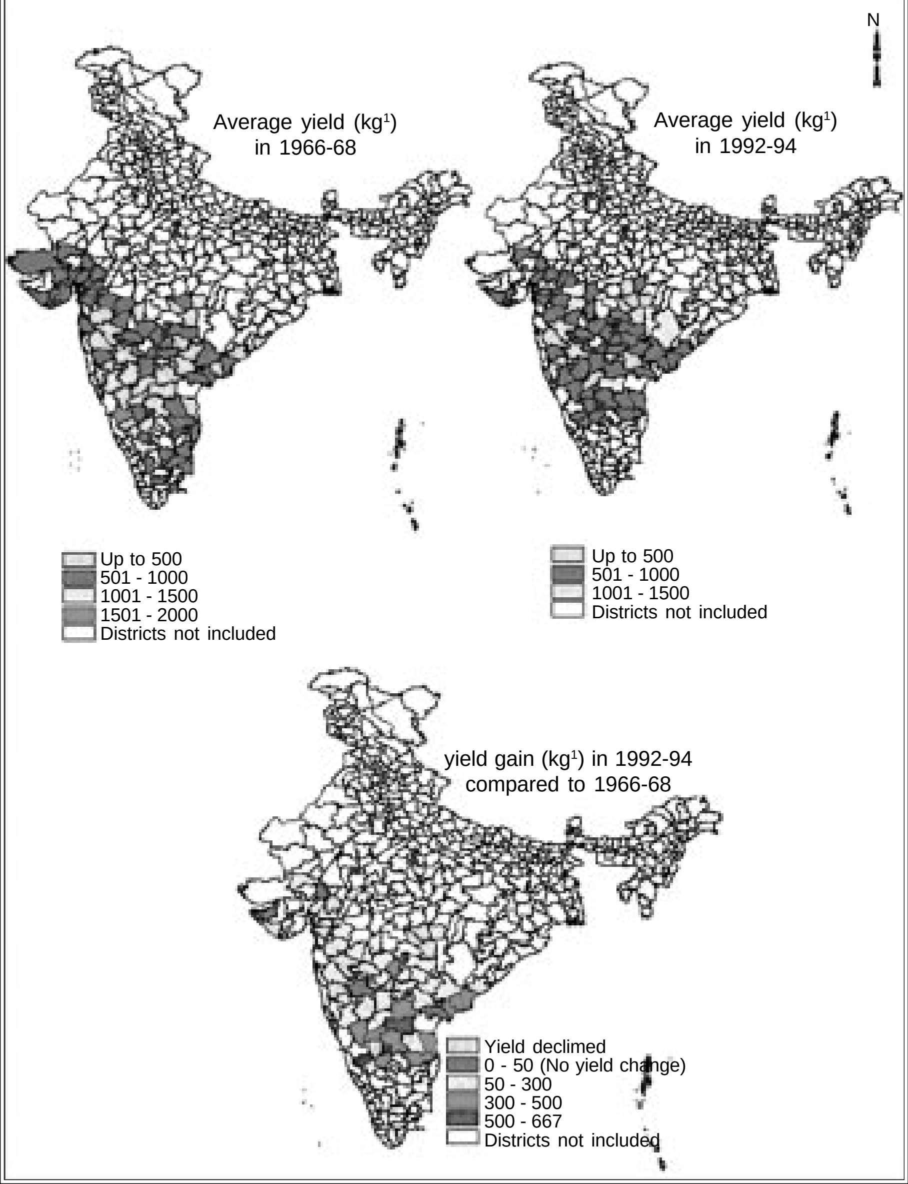
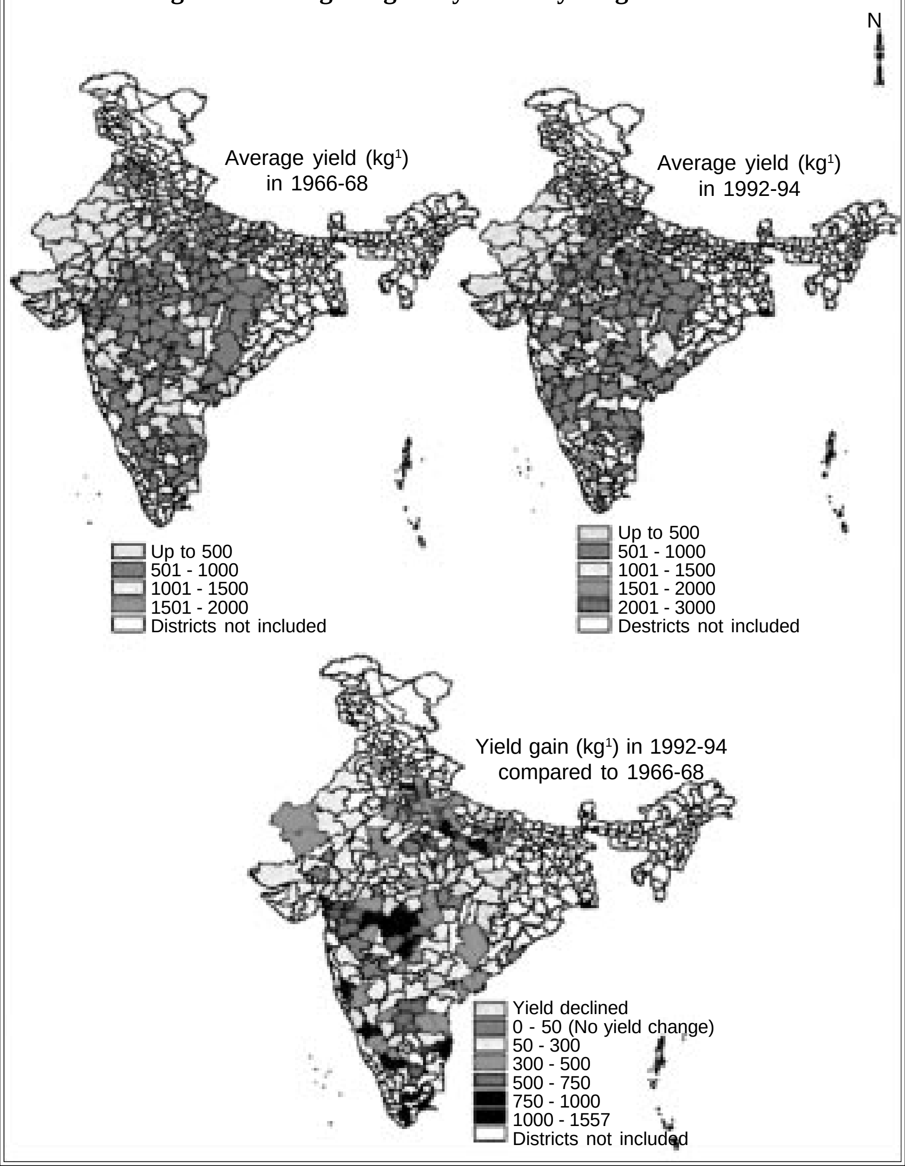


Figure 4. Average sorghum yield and yield gain in India.



An overall increase in sorghum grain yield was observed in a majority of districts (Figure 4). Increase in yield was less in the postrainy season compared to the rainy season. It may be noted that there was an emphasis on research for rainy-season sorghum. There was lesser research and fewer improved cultivars were developed in the case of postrainy-season sorghum. Therefore, it may be concluded that rainy-season research provided improved cultivars suitable for the rainy season, which were then adopted in farmers' fields resulting in greater yield increases. Thus, an increase in rainy-season sorghum's average yield resulted in an overall increase in sorghum yield. Increases in postrainy-season sorghum yield will require improved cultivars which may be developed by greater investment in research.

Reduced Cost of Production

An analysis of the cost of cultivation data in India shows that real cost of production per ton of sorghum declined in the 1980s and 1990s compared to the early 1970s. In Maharashtra, it fell by 40% in the 1990s compared to the 1970s, while it came down by 37% in Rajasthan (Table 3).

Table 3. Impact of improved sorghum cultivars on cost of production[1] per ton in India, 1971-95.

	Average cost (Rs ton^{-1})			Cost reduction (%) compared to the early 70s	
States	Early 1970s[2]	Early 1980s[3]	Early 1990s[4]	Early 1980s	Early 1990s
Karnataka	224	192	231	14	- 4
Madhya Pradesh	223	169	208	24	7
Maharashtra	253	188	153	25	40
Rajasthan	309	264	195	14	37

1 All costs are real cost of production. Real cost in the case of Rajasthan was computed on the basis of 1992 prices, whereas for the other states, it was based on 1989 prices.

2 Early 1970s: For Karnataka (average of 1972-1974), Madhya Pradesh (1976), Maharashtra (average of 1972-74), and Rajasthan (average of 1972-74).

3 Early 1980s: For Karnataka (average of 1981-83), Madhya Pradesh (average of 1981-83), Maharashtra (average of 1982-83), and Rajasthan (average of 1981-1983).

4 Early 1990s: For Karnataka (1991), Madhya Pradesh (average of 1994-95), Maharashtra (1995), and Rajasthan (1992).

Source: Estimated from cost of cultivation reports.

Changes in Average Yield and Yield Instability

Table 4 presents the level and changes in average grain yield and its relative variability from 1966-67 to 1980-81 (period 1) and 1981-82 to 1993-94 (period 2). During period 1, the proportion of area under improved sorghum cultivars was less (< 20% before 1980-81) but it was relatively high during period 2 and gradually increased over time to reach 55% during 1991-92. During period 1, the highest yield per hectare was achieved in Karnataka (985 kg), followed by Tamil Nadu (943 kg), and Madhya Pradesh (729 kg). The lowest yields were observed in Rajasthan (300 kg) and Gujarat (499 kg). During period 2, the highest yield per hectare was observed in Tamil Nadu (1113 kg), followed by Karnataka (957 kg), and Maharashtra (902 kg). The lowest yield was recorded in Rajasthan (412 kg), followed by Gujarat (551 kg) and Andhra Pradesh (661 kg). A comparative analysis of these yield levels shows a general increase, except in Karnataka where it fell by 28 kg. The average yield in India was 582 kg during period 1 and 748 kg during period 2. Coming to yield instability index, it was found that the coefficient of variation (CV) in yield declined in all the states except Gujarat. Given the fact that Gujarat usually contributes less than 3% of total sorghum production and 5% of total sorghum area in India, this implies that the relative variability in sorghum yield has generally declined. At the aggregate level, the CV in sorghum yield in India was 11% during period 1 and 13% during period 2.

Table 4. Average grain yield and relative variability of sorghum in different states of India.

States	Period 1 (1966-67 to 1980-81)		Period 2 (1981-82 to 1993-94)		Change (%)	
	Yield (kg ha^{-1})	CV (%)	Yield (kg ha^{-1})	CV (%)	Yield (kg ha^{-1})	CV (%)
Andhra Pradesh	521	23.02	661	21.66	26.84	-5.91
Gujarat	499	31.55	551	42.51	10.38	34.76
Karnataka	985	26.65	957	23.08	-2.91	-13.40
Madhya Pradesh	729	24.08	896	19.52	22.76	-18.96
Maharashtra	609	29.50	902	26.51	17.99	-6.71
Rajasthan	300	58.62	412	50.77	37.47	-13.40
Tamil Nadu	943	28.13	1113	26.24	17.99	-6.71
India	582	10.59	748	13.02	28.47	22.97

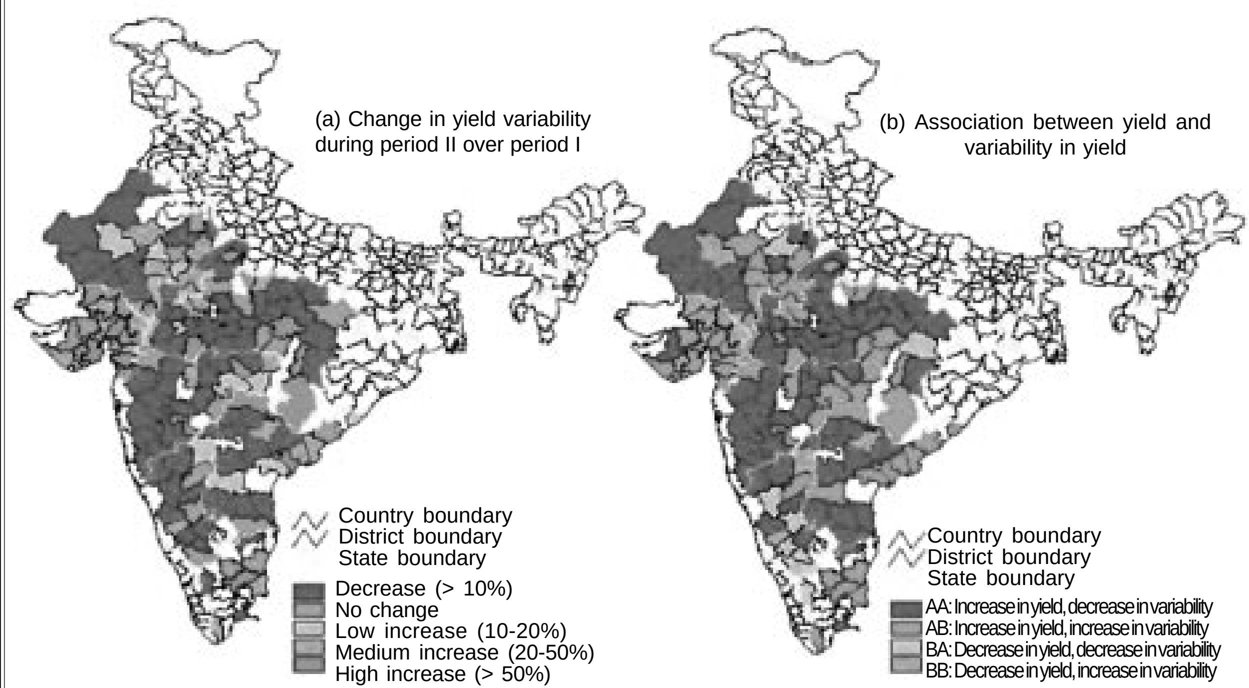
An analysis of the Z* statistics showing the significance in differences in CV between the two periods showed that about 26% of the districts in India comprising only 14% of the total sorghum area, experienced significant increases in CV (Table 5). On the other hand, 39% of the districts comprising 42% of the total sorghum area, experienced a significant decline in CV. This fluctuation over the years is expected to have improved food security in most of the sorghum-producing areas.

Table 5. Districts and sorghum area (%) with statistically significant changes in grain yield variability according to the computed z* statistics.

	Districts (%)		Area (%)	
States	**Increased CV**	**Decreased CV**	**Increased CV**	**Decreased CV**
Andhra Pradesh	25	30	20	43
Gujarat	69	6	76	0
Karnataka	7	36	1	29
Madhya Pradesh	14	50	10	51
Maharashtra	5	45	3	50
Rajasthan	48	43	64	20
Tamil Nadu	33	44	25	52
India	26	39	14	42

The association between sorghum yield and its relative variability is given in Figure 5. Four types of association were found: AA— increase in yield associated with decrease in relative variability, AB — increase in yield associated with increase in relative variability, BA — decrease in yield associated with decrease in relative variability, and BB — decrease in yield associated with increase in relative variability. From the development point of view, AA is the best situation, whereas BB indicates the worst scenario. AB is preferable to BA. The distribution of districts according to the type of association shows that half the districts experienced an increase in yield accompanied by a decrease in variability. More than a third of the districts experienced increase in yield associated with increase in variability, while only 6% showed decrease in yield associated with decrease in variability. Ten districts — Warangal (Andhra Pradesh), Gulbarga and Chikmagalur (Karnataka), Panchmahals, Mehsana, Ahmedabad, Amreli, and Banaskantha

Figure 5. Impact of improved sorghum cultivars on variability in yield in India.



(Gujarat), and Jodhpur and Dungarpur (Rajasthan) — showed a decline in yield associated with increase in variability. The analysis shows that more of the less desirable and most of the undesirable outcomes were experienced by the districts of Gujarat.

Adoption of Improved Cultivars and Yield Instability

An analysis of the relationship between the adoption of improved cultivars and grain yield instability (Table 6) revealed that the rate of adoption of improved sorghum cultivars increased over time in all the states except Rajasthan, where improved cultivars were not adopted on a large scale. An increase in adoption of improved cultivars in Andhra Pradesh, Karnataka, Madhya Pradesh, and Tamil Nadu was accompanied by a decrease in yield instability.

Table 6. Relationship between adoption of improved cultivars and instability in sorghum yield in different states of India.

	Adoption level (%)			Index of yield instability		Change in instability index
States	**1968**	**1981**	**1993**	**Period 1**	**Period 2**	**(%)**
Andhra Pradesh	0.56	20.28	46.76	23.02	21.66	-5.91
Gujarat	0.15	7.78	53.16	31.55	42.51	34.76
Karnataka	3.03	22.76	22.97	26.65	23.08	-13.40
Madhya Pradesh	0.92	29.17	49.48	24.08	19.52	-18.96
Maharashtra	8.47	30.02	68.09	29.50	26.51	-6.71
Rajasthan	0.42	4.64	1.52	58.62	50.77	-13.40
Tamil Nadu	1.35	27.65	99.31	28.13	26.24	-6.71
India	3.68	23.39	52.42	10.59	13.02	22.97

Conclusion

This study had three important outcomes. First, an analysis of the three phases of adoption featured the replacement of traditional varieties with new generations of improved sorghum cultivars. Secondly, there was a significant yield gain and reduction in cost of production per ton with the adoption of improved cultivars. Thirdly, a significant improvement in yield stability was observed and correlated with the uptake of improved sorghum cultivars.

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