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IMPACT OF MODERN CULTIVARS ON GROWTH AND RELATIVE VARIABILITY IN SORGHUM YIELDS IN INDIA*

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ABSTRACT

The nature and extent of growth and variability in sorghum yield is measured in this study to test the hypothesis that rapid technological change increased yield and also instability in sorghum production. Analysis is being based on 146 major sorghum producing districts of India. Annual compound growth rate of sorghum yields for different districts were computed for various periods between 1966 and 1993. Expansion of modern sorghum cultivars positively contributed to the sorghum yield. The coefficient of variation of sorghum yields was estimated for the same districts and from the same set of data after detrending. Analysis showed a general decline in yield variability over time. The coefficient of variation in sorghum yield decreases with the increase in proportion of modern sorghum cultivars. Relative variability of sorghum yield of modern sorghum cultivars, estimated from the experimental data for the period 1982-96, is less than the relative variability of other sorghum cultivars. The study concludes that modern sorghum cultivars contributed to the increase in yield and reduction in relative variability in yield and thereby, enhanced food security in India. It also suggests that future sorghum research in India should be emphasized on yield enhancement rather than on yield stabilization.

Introduction

For sustainable agricultural performance, high growth and low instability in production is a prerequisite. There is a growing concern that rapid technological change in cereal production has increased variability in basic food crops which is reckoned as one of the causes of threat to food security in developing countries. A significant number of studies in recent years have been devoted to analyze the instability in cereal production responding to this concern, yet unable to settle the debate. Some studies have shown that production instability has increased due to the expansion of modern cultivars while others have concluded that production instability has decreased with the expansion of modern cultivars.

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A causal link between growth in agricultural production and instability was first addressed by Sen (1967). The author hypothesized that variability in production increased due to expansion of cultivation to the marginal land and the increased use of purchased inputs. Rao (1975), however, held that since variability in yield tends to be far greater than variability in area, shifting from growth based on expanding area to growth based on increasing yields automatically leads to a tendency toward increased variability in production.

Hazell (1989) observed that production variability in world cereal production increased since the rapid adoption of modern technology. Mehra (1981) also argued that instability in India's total food grain production has increased due to the widespread adoption of the improved seed fertilizer intensive technologies since the mid 1960s. Similar arguments were repeated by Barker, Gabler and Winckelmann (1981) and by Griffin (1988). Carlson (1985) examined the causes of rice yield variability using panel data from 13 Asian countries. He concluded that the coefficients of variation of both rice yields and total production decreased significantly with higher adoption of modern varieties and irrigation development. Mcintire and Fussell (1985) estimated sources of variation in millet grain yield from farm level data in India. The results showed that improved cultivars did not generally contribute to increased relative or absolute variability if accompanied by appropriate package of inputs. Deb, Mandal and Dey (1991), based on secondary data from Bangladesh for the period 1947/48 to 1986/87, showed that absolute variability' in production increased during the modern technology period (1972/73-1986/87) compared to the pre-modern technology period (1947/48-1971/72). They found a decrease in relative variability in the modern technology period. Singh and Byerlee (1990), based on 57 wheat producing countries of the world, showed that relative variability in wheat yield declined over time and expansion of modern wheat varieties have positive contribution to the decrease in variability in wheat yield.

The magnitude of growth in sorghum production and variability in its production has serious implications for food security in India since sorghum is one of the major cereal crops in the country. Information on the contribution of modern sorghum cultivars to the growth and variability in sorghum production would help the policy makers of India to implement policy measures such as food reserves to counter instability and, thereby, to design its procurement and export-import policy for food.

The present study is undertaken to quantify the contribution of modern sorghum cultivars on growth and variability on sorghum yield. The specific objectives of the study are as follows:

(1) to quantify spatial and temporal changes in sorghum yield in India.
(2) to estimate the level of variability in sorghum yield, and
(3) to examine the role of modern sorghum cultivars on growth and variability in sorghum yield.

Section 2 of this paper briefly discusses the sources of data and the analytical procedures used in the study. The results are discussed in Section 3 which is followed by conclusions and policy issues.

Data Sources and Research Methodology

Data

The analysis is based on the secondary data collected from 146 most important sorghum-growing districts in 7 states of India (Madhya Pradesh, Andhra Pradesh, Karnataka, Tamil Nadu, Maharashtra, Gujarat and Rajasthan). The secondary data were assembled by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and the World Bank largely from the Season and Crop Reports and Statistical Abstracts of the concerned states.[2] The data were also collected from experimental on station trials on sorghum yield conducted under the All India Coordinated Sorghum Improvement Project. A district was included in the sample if it has at least an average of 500 ha of area under sorghum cultivation during the period 1991-94. Jamnagar and Kutch districts of Gujarat were not included in the study due to the non-availability of data after 1989. The study districts accounted for over 96% of the all-India sorghum area and 95% of the all India sorghum production. The time series data related to the period from 1966/67 to 1993/94. Experimental level yield data on sorghum yield for different modern sorghum cultivars for the period 1982 to 1996 were taken from the Progress Reports of the All India Coordinated Sorghum Improvement Project.

Analytical procedure

RATE OF GROWTH IN SORGHUM YIELD

Annual compound rate of growth in sorghum yield was estimated using the following equation:

$$\ln Y = a + bt \qquad (1$$

where ln Y is sorghum yield (in kg/ha) and expressed in natural log form, t is the time trend denoting years and 'b' is the annual compound rate of growth in sorghum yield;

DETERMINANTS OF INTERDISTRICT DIFFERENCES IN SORGHUM YIELD

Regression analysis was carried out to examine the impact of modern cultivars and other important factors on sorghum yields. Sorghum yield may be effected by production environment, cultivars used (HYV or local), irrigation, rainfall. Due to non-availability of rainfall data, the empirical regression equation was of the following form:

$$\ln Y = a + b_1 \ln (SORGA) + b_2 PMV + b_2 PIRRG \quad (2)$$

where

ln (SORGA) is the sorghum area in hectares and expressed in natural log. Districts with large sorghum area are expected to grow sorghum over a wider range of agroclimatic environments, which increases the probability of lower average yield of that district. Therefore, it is expected that ln (SORGA) would have a negative coefficient in the estimated regression.

PMV is the proportion of modern cultivars to the total sorghum area.

PIRRG is the proportion of irrigated sorghum area.

RELATIVE VARIABILITY IN SORGHUM YIELD

Production variability may arise due to the variability in area, yield and/or interaction between area and yield. Since variability in yield has been shown to be the main source of production instability (Weber and Sievers, 1985; Hazell, 1985), we focused the analysis exclusively on yield variability. We have measured variability in sorghum yield using the Cuddy-Della Valle index which is adopted in recent years as a measure of variability in time-series data (Weber and Sievers, 1985; Singh and Byerlee, 1990). The simple coefficient of variation over-estimates the level of instability in time-series data characterized by long-term trends whereas the Cuddy-Della Valle index corrects the coefficient of variation, by:

$$CV = (CV^*) (1 - R^2)^{0.5} \quad (3)$$

where :

CV is the Cuddy-Della Valle index, i.e., corrected coefficient of variation(CV). In subsequent discussion it is referred as CV.

CV* is the simple estimate of the coefficient of variation (in percent), and

R^2 is the coefficient of determination from a time-trend regression adjusted by the number of degrees of freedom.

It may be mentioned that some authors have estimated the CV around trend as the standard error of regression divided by the mean. After estimating in both ways from the same set of data Singh and Byerlee (1990) found that the results are almost identical whichever method is used. In their case the correlation between the instability index of two methods were 0.9998. Since both methods provide same results we opted to estimate instability index using Cuddy Della Valle Index. To test the differences in CV between two time periods, Z statistics is computed as:[3]

$$Z = (CV_2 - CV_1)\ \{[1 + 2CV_1)/2](1/n_1 - 1/n_2)\}^{0.5/CV_1} \quad (4)$$

where CV_2 and CV_1 are the CV of Period 2 and 1, respectively; n_1 and n_2 represents the number of years during period 1 and period 2, respectively;

The change in CV for each district was tested using the Central Limit Theorem to compute :

$$Z^* = Y\text{-}Z_i/m^{0.5},$$

where Z_i are the standard normal test statistics for each observation of equation (4) above, and m is the number of observations in the sample.

DETERMINANTS OF RELATIVE VARIABILITY IN SORGHUM YIELD

Regression analysis was carried out to determine whether the technological factors are responsible for variation in CV of sorghum yield in different districts over the period 1966-93. The regression equation was of the following form:

$$CV = a + b_1\ lnY + b_2\ PMV \quad (5)$$

where ln Y is the natural logarithm of sorghum yield in kg per hectare, PMV is the proportion of modern cultivars to the total sorghum area.

Results and Discussion

Table 1 shows the distribution of the study districts. Out of 146 districts 20 were from Andhra Pradesh, 16 from Gujarat, 14 from Karnataka, 42 from Madhya Pradesh, 22 from Maharashtra, 23 from Rajasthan and 9 from Tamil Nadu. During 1991/92 to 1993/94 period, these districts together accounted for 96.2 percent of total sorghum area

and 95.3 percent of sorghum production in India. During this period, contribution of the study districts of Maharashtra, Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Rajasthan and Tamil Nadu to the total sorghum area in India were 46, 8, 5, 17, 11, 6 and 4 percent, respectively. On the other hand, contribution of the study districts of these states to the total sorghum production in India in this period was 49, 8, 3, 17, 12, 2 and 5 percent, respectively.

Using equation (1), we have estimated the annual compound growth rate in sorghum yield for three periods-1966/67 to 1980/81, 1981/82 to 1993/94, 1966/67 to 1993/94. During the first period (1966/67-1980/81) percentage of HYV sorghum area to the total sorghum area in India was less than 20 per cent indicating while in the second period (1981/82-93/94) it was above 20 per cent. This indicates that HYV sorghum cultivation was less intensive in the first period while it was more intensive in the second period. Therefore, these two periods can be considered as early HYV period and HYV period. It may be noted that critics say that HYVs had increased variability in production and our objective is to test this hypothesis. Based on the annual compound rate of growth the districts which can be classified into four categories: Category A (High growth) - districts achieved growth rate 5 per cent or above, Category B (Moderate growth) - districts which achieved growth rate more than 1 per cent but less than 5per cent, Category C (Slow growth)- districts with positive growth rate upto 1 per cent, Category D (Negative growth)- districts having negative rate of growth in sorghum yield in the reference period. Table 2 presents the percentage distribution of districts under these four categories for each of the three periods. During Period 1, 75 percent districts of Gujarat and 50 percent districts of Karnataka experienced high rate of growth in yield whereas in Period 2, 81 and 50 percent districts of these two states experienced negative growth in yield, respectively. It is observed that majority of the districts experienced moderate growth in all the three periods. District wise growth rates are given in Appendix 1.

To determine the effect of environment, modern sorghum cultivars and irrigation on sorghum yield, we carried out a regression analysis using equation (2). The estimated equation is:

$$\ln Y = 6.2346 - \underset{(-2.518)^{**}}{0.053 \ln (SORGA)} + \underset{(9.388)^{**}}{2.204 PMV} + \underset{(0.031)}{0.013 PIRRG} \quad (6)$$

Adj. $R^2 = 0.38$ $n = 146$

Table 1. Distribution of study districts in different states of India

States	No. of Districts	Name of Districts	Total Area ('000 ha)	Total Production ('000 metric Ton)
1	2	3	4	5
Andhra Pradesh	20 (13.7)	Srikakulam, Visakhapatanm, East Godavari, West Godavari, Krishna, Guntur, Nellore, Kurnool Anantapur, Cuddapah, Chittoor, Hyderabad, Nizamabad, Medak, Mahabubnagar, Nalgonda, Warangal, Khammam, Karimnagar, Adilabad	1057 (8.3)	816 (7.5)
Gujarat	16 (11.0)	Ahmedabad, Amreli, Banaskantha, Broach, Baroda, Bhavnagar, Bulsar, Dangs, Junagadh, Kaira, Mehsana, Panch Mahals, Rajkot, Sabarkantha, Surat, Surendranagar	632 (4.9)	295 (2.7)
Karnataka	14 (9.6)	Tumkur, Mysore, Mandya, Hassan, Shimoga, Chikmaglur, Chitradurga, Bellary, Dharwad, Belgaum, Bijapur, Bidar, Raichur, Gulbarga	2159 (16.9)	1816 (16.7)
Madhya Pradesh	42 (28.8)	Durg, Bastar, Raipur, Bilaspur, Surguja, Jabalpur, Balaghat, Chhinwara, Narsimhapur, Seoin, Mandla, Sagar, Damoh, Tikamgarh, Chhatarpur, Panna, Rewa, Sidhi, Satna, Shahdol, Gwalior, Shivpur, Guna, Datia, Morena, Bhind, Indore, Ratlam, Ujjain, Mandsaur, Dewas, Dhar, Jhabua, Khargone, Khandwa, Sehore, Raisen, Vidisha, Betul, Rajgarh, Shajapur, Hoshangabad	1354 (10.6)	1269 (11.7)
Maharahstra	22 (15.1)	Nasik, Dhulia, Jalgaon, Ahmednagar, Pune, Satara, Sangli, Solapur, Kolhapur, Aurangabad, Parbhani, Beed, Nanded, Osmanabad, Buldhana, Akola, Amravati, Yavatmal, Wardha, Nagpur, Bhandara, Chadrapur	5851 (45.8)	5348 (49.3)
Rajasthan	23 (15.8)	Ajmer, Alwar, Banswara, Barmer, Bharatpur, Bhilwara, Bikaner, Bundi, Chittorgarh (Chittor), Dungarpur, Ganganagar, Jaipur, Jaisalmer, Jalore, Jhalawar, Jodhpur, Kota, Nagaur, Pali, Sawai Madhopur, Sirohi, Tonk, Udaipur	715 (5.6)	243 (2.2)

(Contd.

1	2	3	4	5
Tamil Nadu	9 (6.2)	South Arcot, North Arcot, Salem, Coimbatore, Tiruchirapalli, Tanjavur, Mahdurai, Ramnath Puram, Tiruneivell	532 (4.2)	565 (5.2)
ALL INDIA	146 (100.0)		12783 (100.0)	10859 (100.0)

Note: Figures in the parentheses are percentages of all India. Area and production figures represent the average area and production for the period 1991-94. The study districts comprises 96.2 and 95.3 percent of total sorghum area and production, respectively, in India.

It indicates that more diverse the environment of a district, lower the level of yield. On the other hand, higher the proportion of modern variety higher the level of sorghum yield. We could not find any significant effect of irrigation on yield, which is unexpected.

Table 3 presents the relationship between changes in average yield and relative variability in sorghum yield. In period 1 (1981/82 to 1993/94), highest level of per hectare yield was in Karnataka (985 kg) followed by Tamil Nadu (943 kg) and Madhya Pradesh (729 kg) while the yield level of Rajasthan (300 kg) was lowest followed by Gujarat (499 kg). During the period 2 (1981/82 to 1993/94), highest per hectare yield was in Tamil Nadu (1113 kg) followed by Karnataka (957 kg) and Maharashtra (902 kg). Lowest yield level was in Rajasthan (412 kg) followed by Gujarat (551 kg) and Andhra Pradesh (661 kg). During the Period 2 compared to Period 1, yield level in all the states has increased except Karnataka where per hectare sorghum yield has been reduced by 28 kg. Average yield levels in India during Period 1 and Period 2 were 582 kg and 748 kg, respectively. In all the states except Gujarat coefficient of variation in yield has decreased. This implies that except Gujarat in all the states relative variability in sorghum yield has reduced. It may be mentioned here that the study districts of Gujarat contributed only 2.7 percent of total sorghum production and 4.9 percent of total sorghum area in India during 1991-94 period. The coefficients of variation in sorghum yield in India during these two periods were 11 and 13 percent respectively. Implication of this finding is that over time there has been reduction in year to year yield fluctuation. Per hectare yield level of sorghum and coefficient of variation in sorghum yield for individual districts during Period 1 and Period 2 and their changes over time are shown in Appendix 2.

Table 2. Percentage distribution of districts according to the annual compound rate of growth in yield of sorghum in different periods.

States/ Period	Percentage of districts in the category of			
	A: High growth (5.0% or above	B: Moderate growth (> 1.0 to <5.0%)	C: Slow growth (Upto 1.0%)	D: Negative growth
1	2	3	4	5
		1966/67 to 1980/81		
Andhra Pradesh	0.0	70.0	10.0	20.0
Gujarat	75.0	18.8	6.3	0.0
Karnataka	50.0	28.6	21.4	0.0
Madhya Pradesh	0.0	28.6	23.8	47.6
Maharahstra	31.8	68.2	0.0	0.0
Rajasthan	30.4	34.8	4.3	30.4
Tamil Nadu	11.1	55.6	22.2	11.1
INDIA	23.3	41.8	13.0	21.9
		1981/82 to 1993/94		
Andhra Pradesh	5.0	75.0	10.0	10.0
Gujarat	6.3	6.3	6.3	81.3
Karnataka	0.0	28.6	21.4	50.0
Madhya Pradesh	2.4	71.4	21.4	4.8
Maharahstra	13.6	72.7	9.1	4.5
Rajasthan	17.4	17.4	8.7	56.5
Tamil Nadu	33.3	33.3	0.0	33.3
INDIA	8.9	50.0	13.0	28.1
		1966/67 to 1993/94		
Andhra Pradesh	0.0	65.0	35.0	0.0
Gujarat	6.3	25.0	56.3	12.5
Karnataka	0.0	28.6	64.3	7.1
Madhya Pradesh	2.4	57.1	38.1	2.4
Maharahstra	0.0	95.5	4.5	0.0
Rajasthan	17.4	52.2	21.7	8.7
Tamil Nadu	0.0	77.8	11.1	11.1
INDIA	4.1	58.2	32.9	4.8

The association between sorghum yield and relative variability in yield is presented in Table 4. We found four different types of association : 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, 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 situation. AB would be preferred to BA. The distribution of districts according to the types of association between yield and relative variability in yield shows that half of the districts under the study experienced an increase in yield accompanied by decrease in variability. More than one third of the districts experienced increase in yield associated with increase in variability, while only 6 percent districts attained decrease in yield associated with decrease in variability. The number of districts which faced decrease in yield associated with increase in variability is 10. These are Warangal district of Andhra Pradesh; Gulbarga and Chikmaglur districts of Karnataka; Panchmahals, Mehsana, Ahmedabad, Amreli and Banaskantha districts of Gujarat; and Jodhpur and Dungarpur districts of Rajasthan. It appears from the analysis that the districts of Gujarat experienced more of the less desirable and most of the undesirable outcomes.

Table 3. Average yield and relative variability in yield of sorghum in different districts

States/ Districts	Period I (1966-80)		Period II (1981-93)		Percentage change	
	Yield (kg/ha)	CV(%)	Yield (k/ha)	CV(%)	Yield (kg/ha)	CV(%)
Andhra Pradesh	521	23.02	661	21.65	26.84	-5.91
Gujarat	499	31.55	551	42.51	10.38	34.76
Karnataka	985	26.65	957	23.08	-2.91	-13.42
MadhyaPradesh	729	24.08	896	19.52	22.76	-1[illegible]
Maharahstra	609	29.50	902	26.51	17.99	-[illegible]
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

Table 5 shows the relationship between changes in CV and proportion of modern sorghum cultivars. Fifty percent districts experienced a decrease in coefficient of variation in yield by at least 10 percent while CV has increased in 34 percent districts. The area under the districts which experienced 10 percent or more decrease in CV during the period 2 was 60 percent while the area under the districts which experienced increase in CV was only 24 percent. From table 5, it seems that the sorghum area under modern cultivars was evenly distributed among these three types of districts.

To examine the differences in changes in CV between the two periods, the Z statistics was computed for each of the study districts following equation (4). The summary of the analysis is presented in Table 6. It shows that 26 percent districts of India experienced significant increase

able 4. Association between yield and instability in yield of sorghum in different districts

tates	Types of Association			
	AA: Increase in yield with decrease in variability	AB: Increase in yield with increase in variability	BA: Decrease in yield with decrease in variability	BB: Decrease in yield with increase in variability
ndhra radesh	Cuddapah, Nalgonda, Hyderabad, Mahbubnagar, Khammam, Karimnagar, Anantapur, Nellore, Medak, Chittor (55)	Visakhapatnam, Srikakulam, Kurnol, Guntur, East Godavari, West Godavari, Krishna, Adilabad (40)		Warangal (5)
ujarat	Rajkot (6)	Baroda, Surendranagar, Broarch Junagadh, Kaira, Surat, Bhavnagar Sabarkantha, Bulsar (57)	Dangs (6)	Panchmahals, Mehsana, Ahmedabad, Amreli, Banaskantha (31)
arnataka	Bijapur, Tumkur, Bellary, Bidar, Belgaum, Shimoga (43)	Raichur (7)	Mandya, Hassan, Dharwad, Mysore, Chitradurga (36)	Gulbarga, Chikmaglur (14)
adhya radesh	Bhind, Sehore, Rewa, Datia, Morena, Satna, Narsimhapur, Vidisha, Ratlam, Dhar, Shahdol, Khargone, Dewas, Sidhi, Damoh, Hoshangabad, Raisen, Mandsaur, Shivpur, Betul, Chhinwara, Jabalpur, Panna, Ujjain, Raipur, Sagar, Surguja, Guna (67)	Tikamgarh, Balaghat, Seoin, Indore, Shajapur, Rajgarh, Jhabua, Chhatarpur, Mandla, Khandwa, Gwalior, Bastar, Durg (31)	Bilaspur (2)	
aharahstra	Satara, Pune, Kolhapur, Sangli, Nagpur, Jalgaon, Solapur, Aurangabad, Nasik, Beed, Ahmednagar, Parbhani, Akola, Amravati (64)	Wardha, Dhulia, Nanded Osmanabad, Chadrapur, Yavatmal, Bhandara (36)		
ajasthan	Jaisalmer, Jalore, Sirohi, Barmer, Ganganagar, Pali, Bikaner, Udaipur, Bharatpur, Tonk, Alwar (48)	Ajmer, Bundi, Nagaur, Bhilwala, Chittorgarh, Sawai Madhopur, Kota, Jhalawar, Banswara (39)	Jaipur (4)	Jodhpur, Dungarpur (9)
mil Nadu	Ramnathpuram, Mahdurai, North Arcot (27)	Salem, South Arcot, Tirunelveli, Tanjavur, Tiruchirapalli	Coimbatore (11)	

ote : Figures in the parentheses indicate percentage of study districts of the state in the category.

in CV and these districts comprised only 14 percent of total sorghum area in India. On the other hand, 39 percent districts of India experienced significant decrease in CV and those districts comprised 42 percent of total sorghum area in India. This implies that during the second period reduction in yield fluctuation ensured food security in most of the sorghum producing areas in India. Appendix 2 gives the calculated values of Z statistics for individual districts and the districts which have experienced statistically significant change in CV of sorghum yield.

Table 5. Classification of districts and sorghum area by changes in coefficient of variation of sorghum yields, 1966-93.

CV in 1981/82-1993/94 compared to 1966/67-1980-81	Percent of Districts	Percent of Sorghum Area	Percent Area in Sub-class Sown to Modern Cultivars, 1981/82-1993-94
Decrease of 10% or more	51	60	34
Less than ± 1-% change	15	16	33
Increase of 10% or more	34	24	33
	100	100	100

Table 6. Percent of districts and sorghum area in which there was a statistically significant change in yield variability according to the computed z* statistics.

State	Percent of Districts		Percent of Area	
	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
Maharahstra	5	45	3	50
Rajasthan	48	43	64	20
Tamil Nadu	33	44	25	52
INDIA	26	39	14	42

To assess the nature of modern cultivars on yield variability, CV of yield for 11 modern sorghum cultivars were also estimated using the experimental data from the All India Coordinated Sorghum Improvement Project for the period 1982 to 1996. The results are presented in Table 7. The relative variability in sorghum yield varies across varieties and states. However, the relative variability estimated for average yield of all varieties in almost all the states is less than the variability in sorghum yield in period 2 (also see Table 3). This implies that the relative variability in yield would decrease with the expansion of modern cultivars of sorghum.

Table 7. Coefficient of variation (%) of in sorghum yield in different states-based on multi location trial data

Cultivars	CV (%) by States								
	Andhra Pradesh	Gujarat	Karnataka	Madhya Pradesh	Mahara-shtra	Rajas-than	Tamil Nadu	Uttar Pradesh	All India
CSV11	37.41	12.31	21.74	35.76	17.54	23.37	37.21	24.38	8.51
SPV 462	29.60	20.83	22.51	29.56	14.85	27.25	33.11	16.97	6.35
CSV 15	33.57	20.48	30.05	20.64	14.26	33.82	50.71	14.63	6.11
SPV 881	31.20	16.32	28.78	21.73	14.19	43.75	37.55	12.74	9.09
CSH 1	21.50	10.90	18.76	37.46	13.50	17.15	48.20	15.83	7.65
CSH 6	23.30	14.00	14.60	45.92	12.40	14.79	32.93	21.25	10.62
CSH 14	17.18	11.76	22.27	35.26	12.33	27.46	45.44	22.89	5.43
CSH 5	29.22	22.84	35.74	29.17	15.99	42.19	30.12	25.03	11.15
CSH 9	21.97	18.56	33.20	31.89	17.56	37.67	48.56	23.29	8.96
CSH 11	24.05	18.86	31.95	37.11	13.75	39.71	40.68	17.92	14.89
All	21.13	14.89	19.99	25.44	13.07	28.56	28.02	16.75	7.17

To determine the effect of modern sorghum cultivars on relative variability in sorghum yield, regression equations were estimated, where the CV of sorghum yield for the period 1966/67 to 1993/94 was the dependent variable, and independent variables were average sorghum yield (in natural log form) and average proportion of modern cultivars (PMV) in the whole period, average proportion of irrigated area (PIRRGA). Since both the independent variables were found highly correlated separate regression equations were estimated for these variables. The estimated regression equations are given in equation (7) and in equation (8).

$$CV = 187.64 - 24.18 \ln Y \qquad (7)$$
$$(-12.192)^{**}$$
$$\text{Adj. } R^2 = 0.50 \qquad n = 146$$

$$CV = 38.30 - 34.385\ PMV \qquad (8)$$
$$(3.736)^{**}$$
$$\text{Adj. } R^2 = 0.08 \qquad n = 146$$

These equations show that both ln Y and PMV have significant negative effect on CV of sorghum yield. However, no relationship could be found between CV and PIRRGA. The negative sign of the estimated coefficient of ln Y indicates that higher the level of sorghum yield in district lower the level of yield variability in that district. The estimated negative coefficient of PMV implies that higher the proportion of modern sorghum cultivars lower the level of yield variability.

Summary and Conclusion

Estimated results show that there is a wide difference in yield level of sorghum in different districts. Per hectare yield level has increased during 1981/82-1993/94 compared to 1966/67-1980/81 in majority of the districts in India. Modern sorghum cultivars contributed to higher level of yield. The relative variability of sorghum yield has decreased in the second period compared to the first period. Relative variability of sorghum yield of modern sorghum cultivars, estimated from the experimental data, is less than the relative variability of all sorghum cultivars indicating that modern sorghum cultivars contributed to the reduction in relative variability. Therefore, it may be concluded that the expansion of modern sorghum cultivars helped to increase sorghum yield and reduced the relative variability in yield of Sorghum in India. It also suggests that future sorghum research in India should be emphasized on yield enhancement rather than on yield stabilization.

Notes

1. Absulute variability was defined in terms of standrad deviation and variance while coefficient of variation was used to measure the relative variability.
2. We would like to thank T.G. Kelly and P. Parthasarathy Rao for providing us the data.
3. For more details see Kendal and Stewart (1969) and Anderson and Hazell (1989).

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APPENDIX 1

Annual compound growth rate in yield of sorghum in different districts of India in different periods

District	1966/67 to 1980/81	1981/82 to 1980/81	1966/67 to 1980/81
1	2	3	4
Andhra Pradesh			
Srikakulam	3.2	-4.3	0.6
Visakhapatanm	2.2	3.0	1.3
East Godavari	2.3	1.7	1.3
West Godavari	2.9	2.2	1.5
Krishna	2.4	2.7	1.8
Guntur	-1.2	0.9	0.2
Nellore	3.0	5.2	2.2
Kurnool	3.8	2.6	3.9
Anantapur	2.9	3.1	4.6
Cuddapah	0.0	2.2	3.8
Chittoor	-1.1	0.7	1.1
Hyderabad	3.9	2.3	2.6
Nizamabad	0.8	3.3	1.8
Medak	1.9	2.6	0.9
Mahabubnagar	2.5	2.9	1.0
Nalgonda	-0.2	1.4	1.6
Warangal	2.3	1.5	-0.0
Khammam	3.4	-1.6	0.8
Karimnagar	2.6	1.1	1.9
Adilabad	-0.9	3.2	0.2
GUJARAT			
Ahmedabad	6.0	-0.2	0.1
Amreli	8.3	-3.8	-0.8
Banaskantha	13.0	-3.8	0.6
Broach	2.8	0.5	1.8
Bhavnagar	10.1	-5.4	-1.2
Bulsar	6.3	-10.2	0.6
Dangs	52.1	-8.6	11.7
Junagadh	8.6	-8.3	0.2
Kaira	5.7	-8.3	0.3
Mehsana	9.3	-6.3	0.3
Panch Mahals	6.0	-7.9	0.1
Rajkot	12.8	-7.3	2.0
Sabarkantha	6.5	-8.7	0.8
Surat	4.5	-0.3	2.2
Surendranagar	1.7	5.8	1.3
Karnataka			
Belgaum	2.5	0.4	-1.0
Tumkur	1.0	-2.5	0.2
Mysore	3.9	1.5	0.2
Mandya	5.8	-0.8	-0.7

(Contd.)

Appendix 1 (*contd.*)

1	2	3	4
Hassan	6.5	-3.8	0.9
Shimoga	5.7	-0.5	1.2
Chikmaglur	4.4	-1.6	0.5
Chitradurga	5.5	2.8	0.2
Bellary	5.1	-0.9	1.1
Dharwad	6.4	-2.4	-0.0
Belgaum	2.5	0.4	1.0
Bijapur	0.7	1.7	1.4
Bidar	5.9	0.2	1.5
Raichur	3.1	1.0	0.9
Gulbarga	0.8	1.7	0.2
MADHYA PRADESH			
Durg	2.9	0.7	0.8
Bastar	0.1	3.7	1.7
Raipur	-1.0	0.6	-0.1
Bilaspur	-0.4	2.0	-0.0
Surguja	-0.2	1.9	0.9
Jabalpur	-1.3	0.8	0.6
Balaghat	1.7	3.5	1.8
Chhinwara	1.5	5.4	3.9
Narsimhapur	-1.0	3.0	1.4
Seoin	-2.7	1.6	0.9
Mandla	-2.0	2.0	0.2
Sagar	-1.5	1.7	0.0
Damoh	-1.9	1.6	0.6
Tikamgarh	0.4	3.2	1.7
Chhatarpur	0.1	1.0	0.5
Panna	-1.6	1.3	1.0
Rewa	0.9	2.3	2.1
Sidhi	1.2	2.4	1.4
Satna	-3.5	1.9	0.4
Shahdol	-0.1	2.5	1.6
Gwalior	4.0	2.8	2.1
Shivpur	-0.3	0.7	1.0
Guna	-0.6	2.4	1.2
Datia	0.8	2.1	2.8
Morena	-0.4	3.5	1.8
Bhind	-1.3	4.2	1.3
Indore	-1.6	3.3	1.3
Ratlam	-1.1	4.2	1.3
Ujjain	0.7	0.3	2.1
Mandsaur	0.6	0.9	0.8
Dewas	0.8	0.9	0.8
Dhar	1.3	3.8	1.5
Jhabua	1.5	2.1	9.0
Khargone	1.4	3.5	2.7
Sehore	1.3	2.4	2.4
Raisen	2.0	4.7	2.7
Vidisha	0.1	4.0	2.9
Betul	1.9	0.7	2.5

(*Contd.*

Appendix 1 (*contd.*)

1	2	3	4
Rajgarh	1.7	-0.8	0.2
Shajapur	0.1	3.2	1.2
Hoshangabad	-0.6	1.6	0.6
MAHARAHSTRA			
Nasik	10.1	4.0	4.0
Dhulia	5.4	3.9	3.3
Jalgaon	4.8	3.9	3.2
Ahmednagar	3.9	1.2	1.4
Pune	6.0	1.5	2.7
Satara	3.0	2.2	2.9
Sangli	3.6	0.6	2.8
Solapur	1.2	5.6	1.5
Kolhapur	4.3	2.2	3.5
Aurangabad	4.3	4.0	2.8
Parbhani	4.8	3.2	3.6
Beed	4.4	3.4	1.8
Nanded	4.5	5.2	3.3
Osmanabad	5.4	2.4	2.4
Buldhana	6.3	2.6	4.5
Akola	4.2	7.1	4.8
Amravati	7.3	1.5	4.4
Yavatmal	5.5	2.5	4.8
Wardha	4.6	0.8	3.4
Nagpur	4.6	3.5	3.7
Bhandara	1.7	-4.5	0.6
Chadrapur	1.9	2.2	1.7
RAJASTHAN			
Ajmer	-10.1	1.1	0.1
Alwar	6.0	-3.1	0.2
Banswara	4.0	3.6	2.4
Bharatpur	6.8	2.9	2.8
Bhilwara	5.3	-5.9	3.5
Bikaner	4.8	-2.7	1.1
Bundi	1.1	1.4	1.9
Chittorgarh (Chittor)	6.0	-2.8	1.7
Dungarpur	3.9	-1.9	-1.2
Ganganagar	11.0	-2.9	3.0
Jaipur	-8.2	8.7	0.5
Jaisalmer	8.8	-2.2	11.2
Jalore	-7.8	-3.3	9.4
Jhalawar	-0.6	0.3	0.1
Jodhpur	12.8	38.3	1.6
Kota	1.4	0.2	2.8
Nagaur	1.1	15.8	1.3
Pali	2.1	11.7	2.9
Sawai Madhopur	0.6	-2.6	0.7
Sirohi	-1.8	-2.3	5.0

(*Contd.*)

Appendix 1 (*concld.*)

1	2	3	4
Tonk	-3.8	-7.1	-2.1
Udaipur	3.9	-1.3	3.6
Tamil Nadu			
South Arcot	5.7	-0.3	1.2
North Arcot	4.5	4.1	1.5
Salem	1.0	3.3	2.6
Coimbatore	-0.2	-2.4	-0.9
Tiruchirapalli	1.5	8.4	2.1
Tanjavur	0.1	-3.3	0.1
Mahdurai	2.3	6.9	2.2
Ramnath Puram	1.4	5.3	3.3
Tirunelveli	4.9	2.5	1.5
INDIA	2.9	2.3	2.0

APPENDIX 2

Average yield (kg/ha) and relative variability in yield of sorghum in different districts

District	Period 1 1966/67 to 1980/81		Period 2 1981/82 to 1980/81		Percentage Change		Computed Value of Z Statistics
	Yield	CV(%)	Yield	CV(%)	Yield	CV(%)	
1	2	3	4	5	6	7	8
ANDHRA PRADESH							
Srikakulam	524	16.34	596	18.50	13.79	13.24	0.694
Visakhapatanm	522	19.06	592	20.70	13.36	8.61	0.526
East Godavari	512	18.23	593	24.65	15.74	35.20	2.057*
West Godavari	507	16.78	595	22.98	17.37	36.94	1.987*
Krishna	591	21.83	743	34.21	25.63	56.68	3.966**
Guntur	556	22.39	591	26.36	6.22	17.72	1.272
Nellore	390	26.05	491	20.64	26.06	-20.76	-1.733
Kurnool	511	18.77	907	21.90	77.56	16.71	1.005
Anantapur	471	26.75	939	20.77	99.43	-22.35	-1.916
Cuddapah	543	33.44	1010	16.33	85.99	-51.16	-5.480**
Chittoor	729	20.35	907	18.48	24.29	-9.20	-6.00
Hyderabad	548	20.70	748	14.29	36.48	-30.99	-2.056**
Nizamabad	520	32.99	653	23.37	25.60	-29.17	-3.083**
Medak	573	24.12	603	20.42	5.30	-15.33	-1.185
Mahabubnagar	433	26.46	517	19.43	19.53	-26.54	-2.250**
Nalgonda	291	32.35	375	16.08	28.96	-50.30	-5.214**
Warangal	552	18.33	510	27.01	-7.53	47.39	2.784**
Khammam	618	24.48	658	18.17	6.37	-25.77	-2.021*
Karimnagar	506	22.17	649	17.20	28.28	-22.41	-1.592
Adilabad	532	18.82	551	31.70	3.60	68.44	4.129**
GUJARAT							
Ahmedabad	212	44.11	195	63.25	-8.06	43.40	6.132**
Amreli	374	33.97	364	59.35	-2.71	74.74	8.134**
Banaskantha	503	24.82	412	57.59	-17.99	132.00	10.499**
Broach	611	21.64	795	29.69	30.00	37.21	2.580**
Baroda	775	20.27	888	21.22	14.71	4.64	0.301
Bhavnagar	262	46.63	263	90.30	0.39	93.66	13.990**
Bulsar	474	15.59	599	39.18	26.32	151.22	7.561**
Dangs	567	80.98	561	39.50	-0.96	-51.22	-13.287**
Junagadh	673	17.86	687	25.67	2.08	43.74	2.504*
Kaira	600	15.59	647	23.77	7.99	52.50	2.624**
Mehsana	446	29.20	367	39.22	-17.82	34.30	3.209**
Panch Mahals	752	13.39	747	17.92	-0.64	33.87	1.454
Rajkot	319	65.23	447	64.94	40.20	-0.43	-0.091
Sabarkantha	480	15.44	587	36.12	22.15	133.94	6.630**
Surat	817	12.80	1081	22.92	32.27	79.04	3.246**
Surendranagar	116	47.24	168	49.58	45.32	4.95	0.749

Appendix 2 (*contd.*)

1	2		3				4
KARNATAKA							
Tumkur	989	38.28	1008	23.12	1.90	-39.62	-4.858**
Mysore	865	28.63	786	28.08	-9.08	-1.91	-0.175
Mandya	1275	41.71	910	30.02	-28.62	-28.01	-3.742**
Hassan	1298	30.42	1256	23.54	-3.23	-22.63	-2.206*
Shimoga	1705	21.25	1762	19.05	3.35	-10.32	-0.703
Chikmaglur	966	30.77	961	39.39	-0.48	27.99	2.760**
Chitradurga	1469	21.88	1352	21.73	-8.02	-0.71	-0.050
Bellary	940	15.95	992	11.12	5.48	-30.28	-1.548
Dharwad	1088	22.14	915	19.12	-15.95	-13.66	-0.970
Belgaum	741	19.30	827	17.10	11.57	-11.37	-0.703
Bijapur	460	25.54	549	15.35	19.15	-39.87	-3.263**
Bidar	856	31.22	909	24.32	6.26	-22.10	-2.211*
Raichur	590	22.17	626	22.43	6.04	1.19	0.084
Gulbarga	549	23.81	538	28.69	-1.98	20.47	1.562
MADHYA PRADESH							
Durg	878	10.74	901	25.37	2.60	136.26	4.697**
Bastar	778	10.67	1009	19.57	29.70	83.51	2.859**
Raipur	843	20.47	844	17.03	0.03	-16.82	-1.104
Bilaspur	797	22.39	771	16.15	-3.36	-27.88	-2.001*
Surguja	720	12.98	839	12.63	16.67	-2.68	-0.112
Jabalpur	720	20.87	814	16.37	12.95	-21.57	-1.443
Balaghat	989	15.72	1242	16.81	25.56	6.92	0.349
Chhinwara	661	28.89	1168	22.36	76.66	-22.61	-2.093*
Narsimhapur	894	17.36	1129	9.40	26.30	-45.85	-2.525*
Seoin	571	23.44	715	25.24	25.24	7.67	0.576
Mandla	782	16.34	846	26.93	8.23	64.83	3.395**
Sagar	943	20.95	953	19.04	1.06	-9.12	-0.612
Damoh	856	28.14	965	19.65	12.74	-30.18	-2.721**
Tikamgarh	738	25.33	960	26.01	30.01	2.66	0.216
Chhatarpur	751	15.88	812	21.78	8.05	37.16	1.892
Panna	770	30.50	903	24.24	17.27	-20.54	-2.007*
Rewa	520	35.95	673	13.84	29.41	-61.49	-7.082**
Sidhi	641	32.15	748	22.23	16.67	-30.55	-3.147**
Satna	643	31.44	708	16.45	10.03	-47.66	-4.801**
Shahdol	636	31.44	786	19.21	23.55	-38.91	-3.920**
Gwalior	1075	13.47	1363	24.41	26.70	81.21	3.509**
Shivpur	440	37.60	513	27.75	16.63	-26.21	-3.509**
Guna	564	31.11	684	30.72	21.28	-1.26	-0.125
Datia	575	38.28	812	15.39	41.19	-59.79	-7.333**
Morena	717	31.57	916	14.00	27.69	-55.65	-5.628**
Bhind	894	27.25	1099	9.39	22.93	-65.54	-5.723**
Indore	793	11.97	989	13.60	24.65	13.62	0.523
Ratlam	661	26.84	800	15.48	21.12	-42.33	-3.640**
Ujjain	787	23.47	1120	19.01	42.40	-19.03	-1.431
Mandsaur	595	27.65	658	20.29	10.56	-26.62	-2.359*
Dewas	881	21.93	1298	14.75	47.30	-32.75	-2.359*
Dhar	420	37.51	485	22.35	15.41	-40.42	-2.301*
Jhabua	571	19.92	632	26.46	10.53	32.81	-4.858*

(*Contd.*)

Appendix 2 (*contd.*)

1	2		3			4	
Khargone	591	29.45	659	18.88	45.17	-35.87	2.095*
Khandwa	736	15.31	630	25.48	14.22	66.44	-3.385**
Sehore	793	24.25	1126	8.81	41.95	-63.69	3.262**
Raisen	935	12.62	1344	9.26	43.72	-26.63	-4.950**
Vidisha	581	32.54	903	18.73	55.31	-42.43	-1.078
Betul	515	34.85	740	25.80	43.72	-25.98	-2.901**
Rajgarh	647	26.26	673	31.82	4.10	21.18	1.782
Shajapur	890	22.86	1050	27.68	17.94	21.09	1.545
Hoshangabad	844	13.07	925	9.25	9.62	-29.26	-1.227
MAHARAHSTRA							
Nasik	551	38.23	722	30.40	31.19	-20.47	-2.508*
Dhulia	640	23.55	923	24.78	44.27	5.22	0.394
Jalgaon	957	27.00	1368	20.17	43.00	-25.31	-2.190*
Ahmednagar	394	33.90	423	29.68	7.26	-12.44	-1.351
Pune	384	30.24	482	20.29	25.74	-32.90	-3.187**
Satara	672	21.89	977	11.72	45.28	-46.46	-3.260**
Sangli	663	27.88	906	19.25	36.66	-30.97	-2.336*
Solapur	338	33.58	386	26.29	14.28	-21.71	-2.336*
Kolhapur	1191	24.19	1853	16.66	55.61	-31.15	-2.415*
Aurangabad	496	33.81	652	26.57	31.39	-21.39	-2.317*
Parbhani	524	33.75	808	29.62	54.21	-12.25	-1.325
Beed	559	37.11	616	30.14	10.10	-18.80	-2.235*
Nanded	651	41.77	985	44.86	51.29	7.41	0.992
Osmanabad	619	34.57	790	37.42	27.59	8.23	0.912
Buldhana	782	26.18	1445	35.43	84.75	35.35	2.965**
Akola	654	32.89	1222	29.43	86.92	-10.52	-1.108
Amravati	725	26.34	1225	23.79	68.93	-9.68	-0.817
Yavatmal	652	19.63	1259	22.43	92.91	14.24	0.896
Wardha	650	28.24	1030	29.14	58.42	318	0.288
Nagpur	520	26.40	823	18.73	58.26	-29.06	-2.458*
Bhandara	347	23.14	413	28.39	18.90	22.70	1.683
Chadrapur	437	24.71	538	27.95	23.11	13.11	1.038
RAJASTHAN							
Ajmer	101	81.79	158	91.83	55.78	112.27	3.216**
Alwar	334	53.16	408	51.52	22.10	-3.09	-0.527
Banswara	420	36.37	637	65.54	51.55	80.19	9.344**
Bharatpur	418	59.19	519	49.77	24.16	-15.91	-3.018**
Bhilwara	418	59.19	519	49.77	24.16	-15.91	-3.018**
Bikaner	166	43.49	352	55.45	112.44	27.50	3.831**
Bundi	381	46.23	405	35.10	6.19	-24.08	-3.566**
Chittorgarh (Chittor)	562	32.34	690	43.60	22.80	17.56	2.397*
Dungarpur	530	26.46	400	35.09	-24.54	32.61	2.764**
Ganganagar	341	59.06	407	39.21	19.30	-33.62	-6.360**
Jaipur	187	81.73	184	52.99	-1.60	-35.17	-6.360**
Jaisalmer	145	83.36	418	30.45	188.59	-63.36	-16.918**
Jalore	174	72.72	408	27.91	133.94	-61.62	-14.355**
Jhalawar	534	21.42	558	31.17	4.41	45.51	3.124**
Jodhpur	142	100.36	113	111.55	-20.67	11.15	3.586**

(*Contd.*

Appendix 2 (*concld.*)

1	2		3			4	
Kota	539	17.18	869	23.31	61.19	35.66	1.964*
Nagaur	163	59.60	241	72.90	48.38	22.31	4.260**
Pali	123	118.79	158	79.20	28.90	-33.32	-12.680**
Sawai Madhopur	452	36.29	571	48.95	26.22	34.87	4.054**
Sirohi	191	81.03	406	33.25	112.13	-58.96	-15.305**
Tonk	191	54.56	212	50.59	11.01	-7.28	-1.273
Udaipur	286	63.02	456	52.13	59.29	-17.29	-3.490**
TAMIL NADU							
South Arcot	1145	39.05	1200	42.25	4.79	8.17	1.022
North Arcot	1024	33.55	1083	21.45	5.78	-36.06	-3.876**
Salem	754	22.97	1110	23.50	47.31	2.32	0.171
Coimbatore	630	27.48	537	13.08	-14.90	-52.40	-4.614**
Tiruchirapalli	616	15.88	805	30.91	30.63	94.68	4.821**
Tanjavur	1177	31.07	1335	45.60	13.43	46.74	4.268**
Mahdurai	987	25.78	1207	12.47	22.36	-51.65	-4.268**
Ramnath Puram	781	32.34	1188	10.21	52.02	-68.42	-7.089**
Tirunelveli	1373	25.05	1549	36.71	12.85	46.55	3.736**
INDIA	582	10.59	748	13.02	28.47	22.97	0.781