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Rainy Season Sorghum Technology
Adoption and Impact Study in Maharashtra

D Kumara Charyulu, D Moses Shyam, Cynthia Bantilan, ST Borikar, A Ashok Kumar and Belum VS Reddy

INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS

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This work has been undertaken as part of the CGIAR Research Program on Policies, Institutions and Markets

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Acronyms

AICSIP	All India Coordinated Sorghum Improvement Program
CSH	Coordinated Sorghum Hybrid
DSR	Directorate of Sorghum Research
FAO	Food and Agriculture Organization
FHP	Farm harvest price
FCDS	Food Characteristic Demand System
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IFPRI	International Food Policy Research Institute
IIMR	Indian Institute of Millets Research
IMPACT	International Model for Policy Analysis of Agricultural Commodities and Trade
MH	Maharashtra
MSP	Minimum Support Price
MTW	Marathwada
NFSA	National Food Security Act
NSSO	National Sample Survey Organization
OPV	Open Pollinated Variety
PDS	Public Distribution System
QUAIDS	Quadratic Almost Ideal Demand System
SURE	Seemingly Unrelated Regression Estimates
TAO	Taluka Agricultural Officer
UCR	Unit Cost Reduction
VDB	Vidarbha
WMH	Western Maharashtra

Executive Summary

This study on 'Rainy season sorghum technology: Adoption and impact in Maharashtra' was attempted to estimate the adoption of improved varieties and hybrids of rainy season sorghum in the three major regions of Maharashtra and its impact on the yields and incomes of the farmers and consumers in the state. The study was focused on the 13 major districts of Maharashtra where rainy season sorghum is grown and on 91 tehsils where the area under rainy season sorghum was at least 5000 ha per tehsil. These 91 tehsils together accounted for 77.2% of the total rainy season sorghum area in the state. A sample of 20 tehsils was drawn by giving weights to sorghum area and 360 farmers were chosen randomly as sample from 60 villages in 20 tehsils. One-half of the sample was drawn from Marathwada region, while Western Maharashtra and Vidarbha regions accounted for one-fourth of the sample each. The field survey was carried out during 2013 and the household data was pertained to the cropping year, 2012-13.

The analysis of data revealed that rainy season sorghum was quite important in the cropping patterns of the sample farmers. The farmers were largely dependent on farming for their incomes; were in their middle age; had long experience with the rainy season sorghum; and had families with adverse sex ratios. Their size of holding averaged 3.16 ha, with irrigation coverage for about one-fourth of the holding. The survey showed that improved varieties spread is insignificant, while hybrids are popular with farmers. Hence, the study concentrated on hybrids adoption and their impact in the state. The first adoption patterns revealed that the hybrids took about 10 to 15 years to reach peaks of first adoption after their formal release. The cumulative adoption data endorsed the popularity of CSH 9, despite the arrival of private sector hybrids like Mahyco 51, MLSH 296, JKSH 22 and ProAgro 8340. In spite of the availability of information from research and extension departments, farmers predominantly accessed both information as well as seeds from local seed shops before adopting new hybrids. In the latest years, MLSH 296 (Dev Gen), CSH 9, ProAgro 8340, Mahyco 51 and JKSH 22 were the most popular hybrids in Maharashtra.

Despite a depressing policy scenario and discrimination against sorghum, the public and private research investments in sorghum research were productive in increasing the yields of sorghum by 1% per year. Rainy season sorghum area in Maharashtra was nearly saturated with hybrids by the end of the 20th century itself. In this study, the performance of the hybrids released before the year 2000, and those released after were compared to judge whether the new hybrids had shifted the production function to the right and resulted in reduction in the unit cost of production. It was found that the weighted average unit cost of the hybrids released before 2000, was higher by USD 27 per ton when compared with the same of hybrids released after 2000. By reducing the unit cost of production by about 15%, the new set of hybrids resulted in substantial welfare benefits to the society. Using the *ex-post* framework developed by Bantilan et al. (2013), the welfare benefits of new hybrids in Maharashtra were estimated as USD 150 million during 30 years period ie, between 1993 and 2022. Thus, the new production technology of rainy season sorghum has benefitted the farmers as well as the consumers and also seed companies, seed dealers and other actors in the input delivery and output marketing channels.

1. Introduction

Globally, sorghum is an important food crop and occupies fifth place among the food crops in the world. It is a crop of the semi-arid tropics and is grown largely as a rainfed crop. It is a staple food crop to many poor peasants in Africa and Asia. In 2012, sorghum production in the world totalled 57.2 m tons, but it increased to 68.9 m tons in 2014 (FAOSTAT, 2016). United States, India, Nigeria, Mexico, Sudan, Australia and Argentina are the important sorghum producing countries in the world. China, Ethiopia and Brazil follow them closely in terms of production. While the African countries and India have larger areas under sorghum, their productivity levels are quite low. Israel and Jordan have the highest yields of sorghum. It is used as livestock feed and fodder in United States and Europe; for grain and fodder in Africa and India; for making alcoholic beverage in China and Africa; for culinary uses such as porridge making; as well as starch making, wallboard preparation etc in different parts of the world. The sorghum area in the world is slightly increasing and reached 44.9 m ha in 2014 (FAOSTAT, 2016). The world productivity has increased significantly, on average, from 890 kg ha^{-1} in 1966 to 1533 kg ha^{-1} (72.2%) by 2014 (see Figure 1).

Sorghum is one of the important food crops in India. It was the most important source of staple food and fodder in the predominantly rainfed areas of the country a few decades ago. Its grain has very high nutritive value for human consumption and livestock also relish its straw, both in fresh and dried forms. During the last six decades, the consumption preferences of human beings changed in favour of taste and convenience from health and nutrition. Expansion of irrigation facilities caused a drastic change in the cropping patterns: moving away from the coarse cereals to fine cereals such as rice and wheat as they recorded even faster gains in productivity. The policies of the government, in its anxiety to increase food production at a fast pace, have further accelerated growth in the production and consumption of fine cereals. Heavy subsidies provided by the government to rice and wheat in the public distribution system have led to the substitution of coarse cereals by the fine cereals in the consumption patterns of both the rich and the poor as well as urban and rural people. Coarse grains were discriminated against by the support price policy of the government in the procurement of grains when market prices fell below the support prices declared. The difficulties in storage and preservation of coarse grains such as sorghum might be partly responsible, but it was the bias in favor of fine cereals virtually in every policy of the government that hastened the replacement of coarse cereals by the fine cereals in area coverage, production and consumption. To ensure food security of the poor in both rural and urban areas of India, the latest policy of the government promises the supply of rice at Rs 3 kg^{-1}; wheat at Rs 2 kg^{-1}; and coarse grains like sorghum at Rs 1 kg^{-1} (The National Food Security Act 2013). In the face of dwindling production

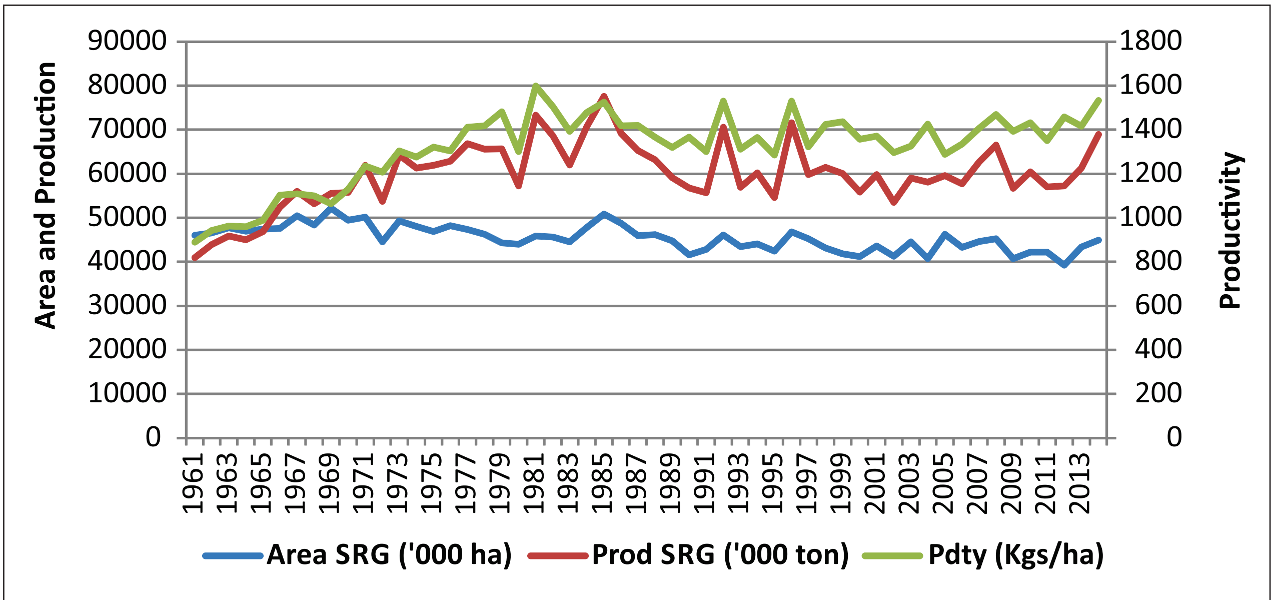


Figure 1. Global sorghum area, production and productivity, 1961-2014.

Source: FAOSTAT, 2016

of coarse cereals in the country, the ability of the government to procure coarse cereals at the market or support prices and supply them to the consumers at Rs 1 kg^{-1} appears to be difficult.

In the rainfed production environment, the productivity gains achieved by sorghum are quite impressive and they were made possible by the introduction of hybrid cultivars, particularly in the rainy season. Rapid increase in the use of tractors reduced the need for bullocks and the use of chemical fertilizers has caused a reduction in the number of cows and less productive milch animals. During the last six decades, livestock population has stagnated in India even as human population has increased rapidly. Accordingly, the need for growing crops like sorghum that yield nutritive straws has nosedived. Despite all the increases in productivity, sorghum cultivation remained a less profitable enterprise and farmers are switching away land from it to more remunerative crops such as soybean, cotton, green gram etc. The logic behind farmers' decisions has to be appreciated. Despite the reduction in area under sorghum, the hard work done by research institutions and seed companies to incorporate high yield, better quality and disease and pest tolerance in the new varieties deserve recognition. Their work has helped farmers in release area for other crops while keeping up production to meet the needs of their families and market demand. The new positioning of coarse cereals such as sorghum and millets as 'nutrition cereals' and coupled with new innovations in the food industry to diversify their use holds some promise. However, this needs to be backed up by the willingness of consumers to pay higher prices for sorghum and its value added products to improve their health and combat lifestyle diseases such as diabetes. Changing climates and depleting water resources may also help the revival of water-efficient crops like sorghum but this is only probable in the distant time horizon.

In the light of changing global scenario of sorghum with respective to area, utilization and policies a need was felt to study in-depth situation of sorghum in heartland such as Maharashtra state of India to find ways of enhancing sorghum area of cultivation and productivity through a planned survey. It is imperative to know the importance of this crop in the state and to estimate the adoption of improved varieties and hybrids across regions. It will be also interesting to quantify the impact of improved rainy sorghum season technology on the farm-yields and incomes of the farmers in the state. The policy bias against rainfed agriculture, especially on coarse cereals need to be reviewed and documented over period of time. The importance of networks in enhancing the technology adoption as well as perceptions of farmers' on agricultural intensification and sustainability etc should be understood well for before targeting and designing of new technologies.

With these broad objectives in mind, the present study is carried out more systematically using both primary and secondary sources of information. The comprehensive report is organized in to seven chapters for better clarity and brevity of results. Chapter 1 highlights the importance and utilization pattern of sorghum globally and India. Chapter 2 summarizes the performance of rainy season sorghum in India, major states and study districts of Maharashtra. The historical development trend of rainy season sorghum improved cultivars and government policy bias against coarse cereals are reviewed and presented in Chapter 3. The details about sampling framework and methodology used for quantification of welfare benefits are furnished in Chapter 4. Chapter 5 briefs the details about field reconnaissance survey, primary household survey, data collection and data validation etc. The key findings emanated from the study are summarized in Chapter 6. The summary and conclusions are discussed in Chapter 7.

2. Performance of Rainy Season Sorghum

2.1 Sorghum at the all-India level

In 1970-71, the area under sorghum was about 17.4 m ha, comprising 10.9 m ha in the rainy season and 6.5 m ha in the postrainy season (Table 1). The production of sorghum was 8.1 m tons at an average yield of 467 kg ha^{-1}. The production in the rainy season was 5.8 m tons at an average yield of 533 kg ha^{-1}, while it was 2.3 m tons in the postrainy season with an average productivity of 354 kg ha^{-1}. However, due to a host of reasons, the area under sorghum dropped to 6.1 m ha in 2014-15, registering a drop of 65% over a period of four and half decade. It is interesting though that the fall in sorghum production was restricted to only 33.3% in the same period, owing to an increase in productivity by 89%. The fall in area for rainy season sorghum was even sharper by 79%, despite an increase in productivity by 90%. The production of rainy season sorghum fell by 60% to 2.3 m tons. In a relative sense, sorghum area in postrainy season fell moderately by only 41%. The production of postrainy season sorghum has increased by 35% due to spurt in its productivity by 128%.

Both the area under postrainy season sorghum as well as its production currently exceed the figures for the rainy season, although productivity for postrainy was lower by 20% than in the rainy season. It is interesting to note that the sorghum area in the rainy season dropped faster despite recording higher productivity. The fact that grain and straw from postrainy produce, being of better quality, received better prices partly explains the slower fall in sorghum area in the postrainy season. The sharper fall in rainy season area was largely due to the wide range of alternative crops feasible in the rainy season when compared with rather limited options available in the postrainy season.

Figure 2 clearly shows the fall in area under sorghum in India after 1968-69, which accelerated after 1986-87. The production of sorghum touched a peak in 1988-89 and regained the peak again in 1992-93. It started falling after that and the fall became sharper after 1994-95 due to rapid fall in area.

Figure 3 depicted the behavior of rainy (*kharif*) season area and production *vis-a-vis* the area and production of sorghum in the postrainy (*rabi*) season. The rainy season sorghum area, depicted by blue

Table 1. Change in area, production and productivity of sorghum at the all-India, 1970-2015.

Item	1970-71	2014-15	Change (%)
Rainy season area (m ha)	10.9	2.2	-79.8
Rainy season production (m tons)	5.8	2.3	-60.3
Rainy season productivity (kg ha^{-1})	533	1014	90.2
Postrainy area (m ha)	6.5	3.8	-41.5
Postrainy production (m tons)	2.3	3.1	34.8
Postrainy productivity (kg ha^{-1})	354	808	128.2
Total area (m ha)	17.4	6.1	-64.9
Total production (m tons)	8.1	5.4	-33.3
Total productivity (kg ha^{-1})	467	884	89.3

Source: Ministry of Agriculture, GOI

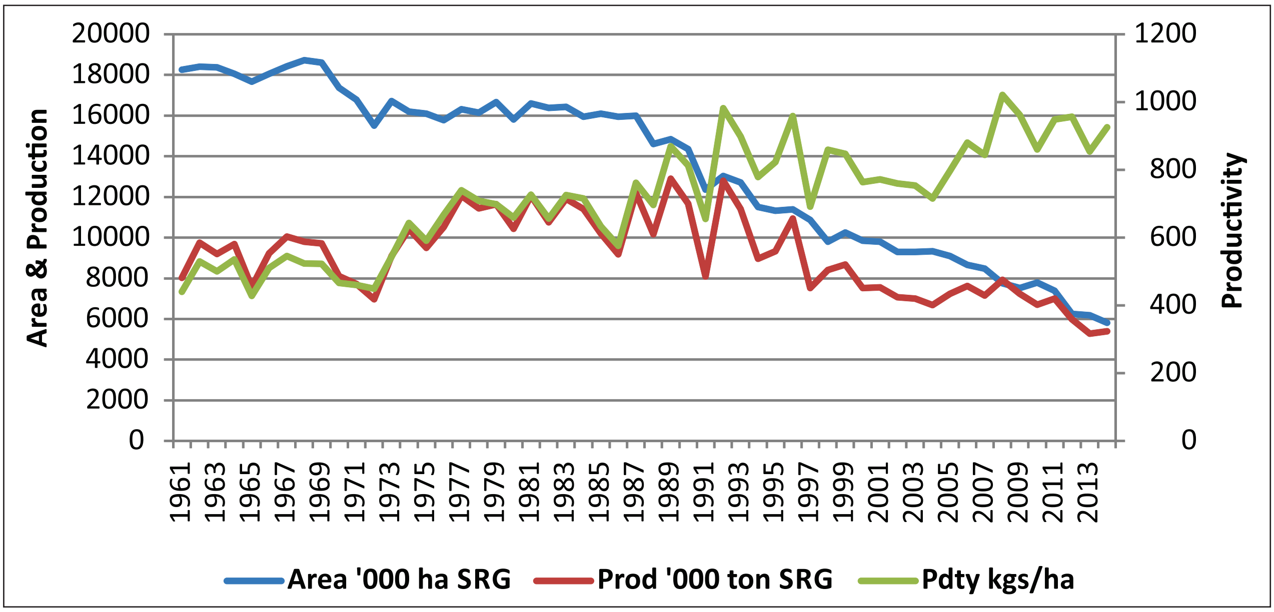


Figure 2. Sorghum area, production and productivity pattern in India, 1961-2014.

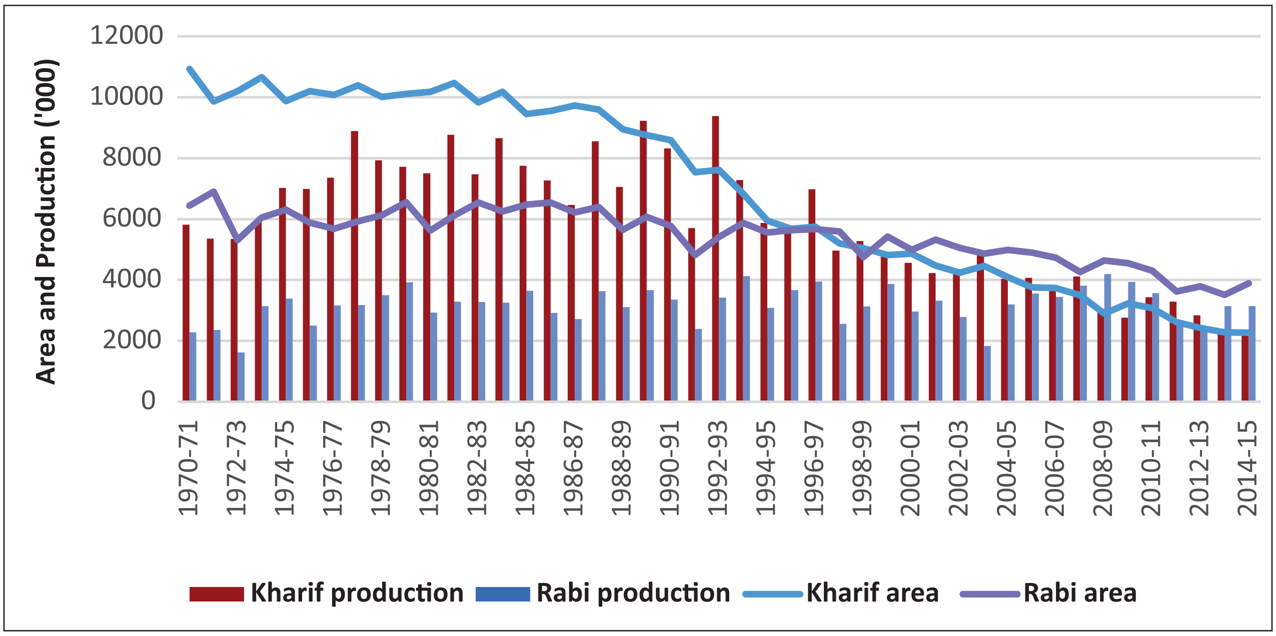


Figure 3. Performance of rainy season and postrainy sorghum in India, 1980-2014.

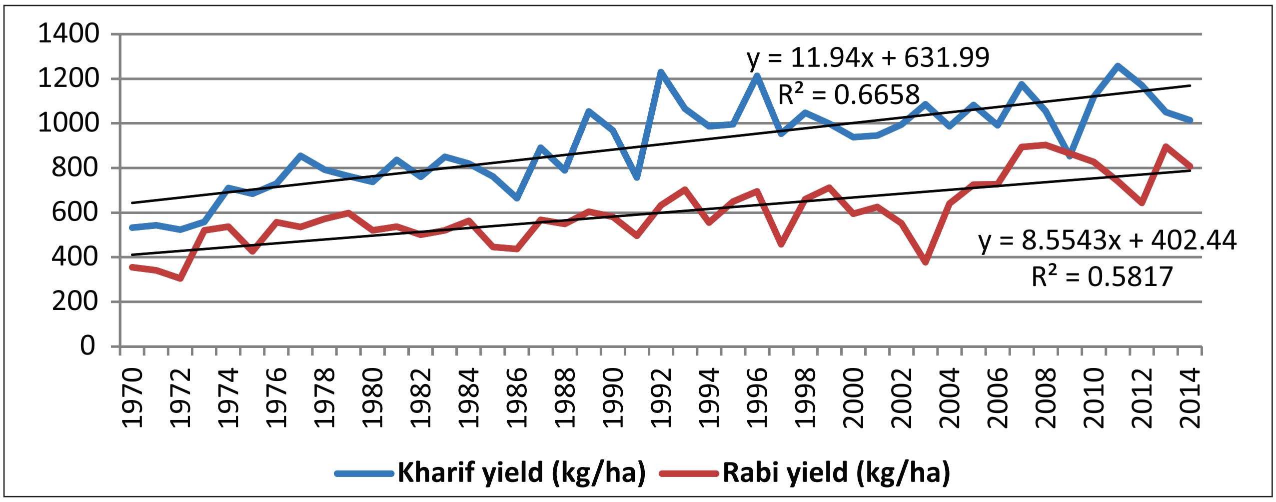


Figure 4. Sorghum productivity at all-India level, 1970-2014.

line, showed a steady and rapid decline all through the study period from 1970-71 to 2014-15. The area of sorghum in the postrainy season, depicted by a violet line, remained stable till 1986-87 despite year to year fluctuations. After that, it showed a declining trend but at much slower pace than that seen in rainy season sorghum area. By the end of the 20^{th} century, sorghum area in the postrainy season exceeded that of the rainy season and the schism widened further by 2014-15. Yet, due to higher productivity of sorghum in the rainy season, the production of sorghum in the rainy season (depicted by red bars) was higher than that in the postrainy season (shown by peacock blue bars) till 2007-08. But after that, the production of sorghum in the postrainy season exceeded that of the rainy season.

Long-term growth trends were computed for the productivity of sorghum in the rainy and postrainy seasons for the period 1970 and 2014 (Figure 4). The blue graph and trend line depicted the growth in productivity of sorghum in the rainy season. The trend equation showed that the productivity of sorghum in the rainy season increased by about 11.94 kg per year over the four and half decades period. The productivity of sorghum in the postrainy season and the trend line fitted are shown in red. The trend line was less steep compared to the rainy season and it estimated that the productivity of sorghum in the postrainy season increased by 8.5 kg per year during the four and half decade period 1970-2014.

2.2 Performance in major states

Triennium and quinquennial averages were computed for the area, production and productivity of rainy season sorghum in the important sorghum growing states of the country at decadal intervals to study the trends over the four decades period (Table 2). During 1966-68, Maharashtra had the highest area under rainy season sorghum, distantly followed by Madhya Pradesh, Karnataka, Andhra Pradesh, Gujarat and Rajasthan. In terms of productivity, however, Madhya Pradesh occupied the top position, followed by Maharashtra, Karnataka, Andhra Pradesh, Rajasthan and Gujarat. Madhya Pradesh stood at the top in terms of production, followed by Maharashtra, Karnataka, Andhra Pradesh, Rajasthan and Gujarat. Even in 2010-14 (quinquennial), Maharashtra retained the top spot in both area and production. While Rajasthan occupied the second rank in area, Madhya Pradesh stood second in rainy season sorghum production.

While Maharashtra lost about 70% area over the four decades period, Rajasthan also suffered an erosion of 41% in area. Madhya Pradesh witnessed a rapid fall in area by 87% over the study period. The fall in the rainy season sorghum area in Karnataka was equally sharp (86%), another important state for rainy season sorghum cultivation. Gujarat and Andhra Pradesh recorded the steepest falls in the rainy season sorghum area by 94% and 98 % respectively.

Overall, productivity growth in case of rainy season sorghum was most impressive in Gujarat, followed by Andhra Pradesh, Karnataka and Rajasthan. Relatively, a modest growth in productivity was reported by Madhya Pradesh and Maharashtra. After Andhra Pradesh and Madhya Pradesh, Karnataka and Gujarat occupied the third and fourth places respectively in terms of productivity during 2010-14. The productivity in Andhra Pradesh was far above the country's average. The productivity of rainy season sorghum was the lowest in Rajasthan state among the major states.

The productivity of sorghum during the rainy (*kharif*) and postrainy (*rabi*) seasons was plotted in the form of graphs and trend lines were fitted for the period of 4.5 decades (see Figure 5). The linear trend equation (displayed in blue) for the rainy season productivity had a steep slope and predicted that productivity was increasing at the rate of 15 kg ha^{-1} per year. But the trend line fitted for the productivity of postrainy sorghum (denoted by red) had a much gentler slope and predicted that the productivity was rising only at the rate of 6.8 kg ha^{-1} per year.

2.3 Yield at the all-India level and in Maharashtra

The productivity of rainy season sorghum at the all-India level is plotted in Figure 6. To obtain better fits of trend lines, two separate trend lines were fitted for the periods 1970-92 and 1993-2014. While the trend line for the first sub-period did give a reasonable fit, the one for the second period gave a poor fit. The trend line for the first period gave a slope of 18.92, implying that the productivity increased by about 19 kg ha^{-1} per year between 1970 and 1992. It was the time when the initial generations of hybrids were introduced during the rainy season and they caused a big spurt in productivity. Besides being a poor fit,

Table 2. Rainy season sorghum performance in major producing states.
(Area – m ha; Prod – m tons and Yield – kg ha^{-1})

	1976-1978			1986-88			1996-1998			2010-2014		
State	Area	Prod	Yield	Area	Prod	Yield	Area	Prod	Yield	Area	Prod	Yield
Andhra Pradesh	1.21	0.56	468	1.12	0.61	539	0.81	0.45	550	0.02	0.05	1923
Gujarat	1.14	0.22	195	0.85	0.41	490	0.63	0.20	313	0.07	0.09	1318
Karnataka	1.21	0.68	564	0.96	1.04	1089	0.79	0.86	1075	0.17	0.24	1438
Maharashtra	2.68	1.71	636	3.10	3.18	1026	2.85	2.82	982	0.79	1.00	1262
Rajasthan	1.08	0.32	294	0.79	0.32	408	1.01	0.34	334	0.64	0.44	687
Madhya Pradesh	2.41	1.74	725	1.89	1.32	699	1.86	1.55	835	0.31	0.50	1611

Source: Directorate of Economics & Statistics

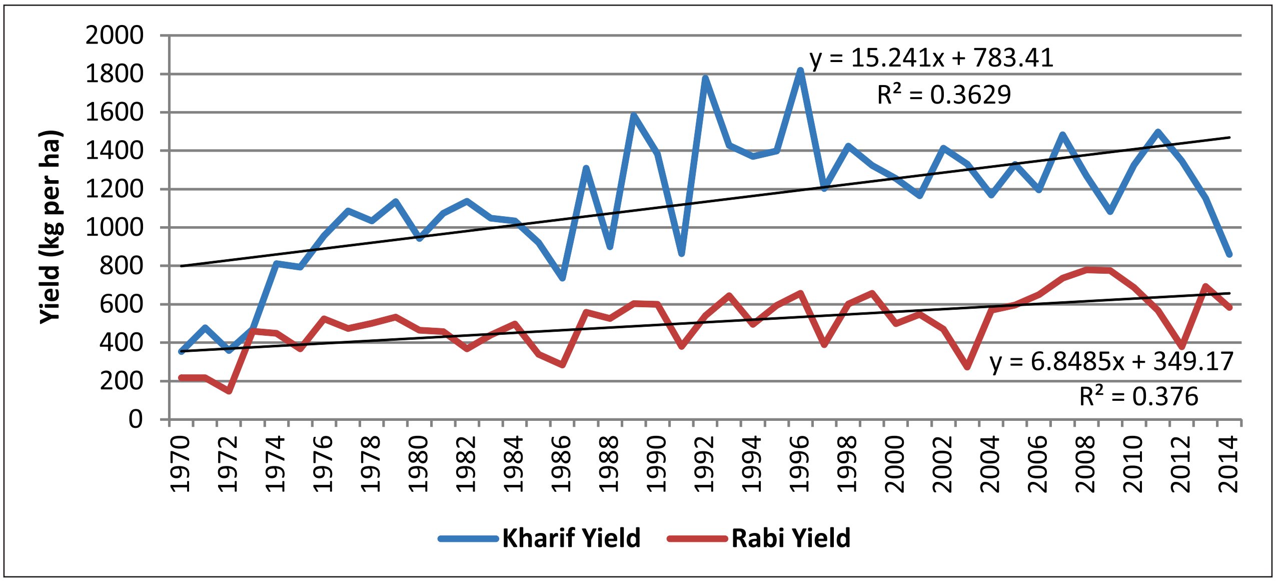


Figure 5. Sorghum productivity levels in Maharashtra state.

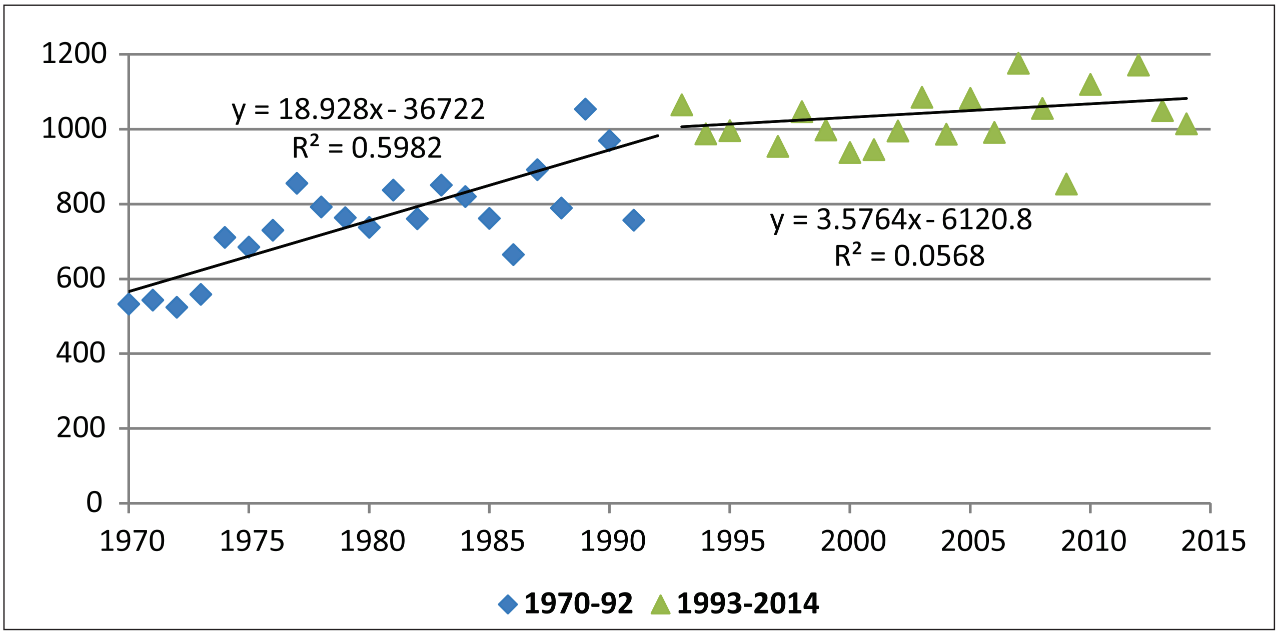


Figure 6. Performance of rainy season sorghum yield at the all-India level.

the trend line for the second sub-period was rather flat and indicated that the productivity increased by only 3.5 kg ha^{-1} per year during the second sub-period of 1993-2014. During this period, new hybrids were introduced to replace the old ones. But their impact in terms of increasing productivity was rather weak. In this phase, the green revolution technologies failed to create big jumps in productivity unlike the case in the early green revolution period. Yield stagnation could also have occurred due to the diversion of productive lands to more remunerative crops and relegating sorghum to only marginal lands.

Just as in case of all of India in Figure 6, the productivity data for rainy season sorghum in Maharashtra were plotted in Figure 7. The time period of four and half decades was split in to two equal periods and two separate trend lines were fitted for the two sub-periods, 1970-92 and 1993-2014. Just as in case of all-India, the trend line for 1970-92 gave a good fit, while the one for the second period gave a poor fit. The trend line for the period, 1970-92, gave a prediction that the productivity increased by 39.14 kg ha^{-1} per year during this period. The trend line for the second sub-period, 1993-2014, displayed a negative slope and indicated that the sorghum yield in Maharashtra during the rainy season actually fell by about

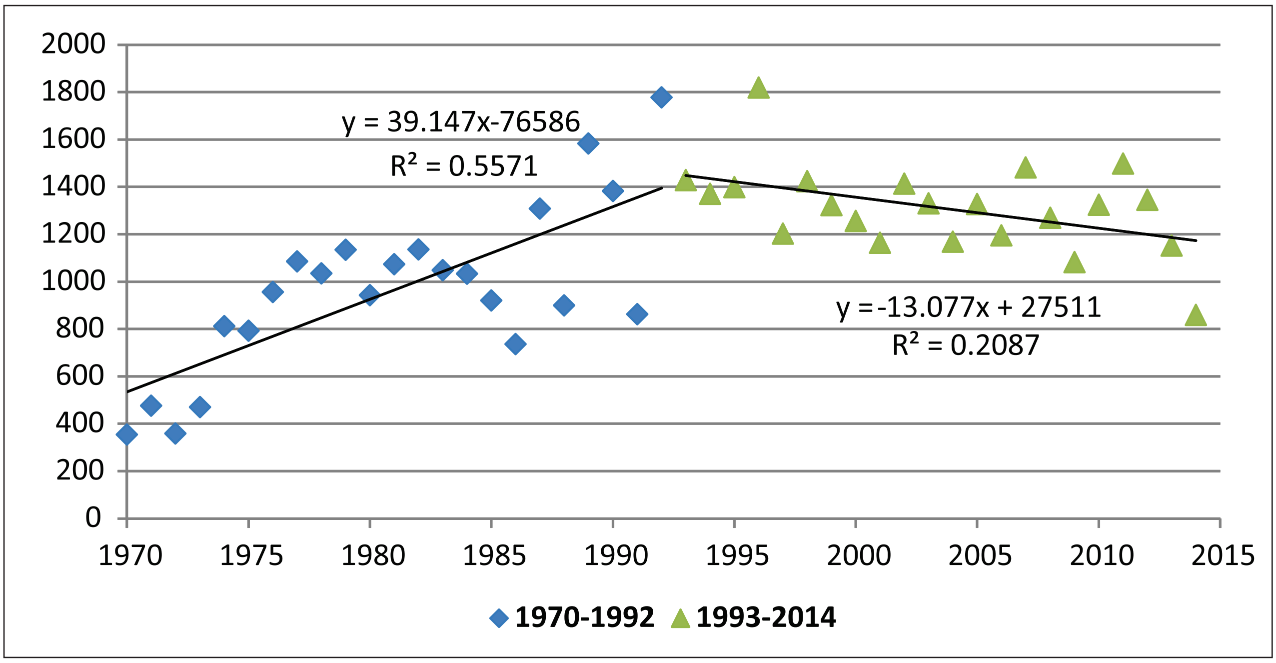


Figure 7. Performance of rainy season sorghum in Maharashtra.

13 kg ha^{-1} per year. This yield reduction could be because of diversion of good quality lands from sorghum to more remunerative crops such as cotton and soybean and relegating sorghum to only marginal lands. But, in view of the poor fits obtained for the trend lines fitted on rainy season sorghum yields during 1993-2014 both for all-India and Maharashtra, it may be better to rely on the trend lines fitted for the four and half decade period.

2.4 Study districts of Maharashtra[1]

Among the districts of Maharashtra, the top 13 districts were selected for detailed study of the performance of rainy season sorghum. These 13 districts accounted for 84.60% of the rainy season sorghum area in Maharashtra. They together had a share of 79.50% in sorghum production during the rainy season. Their combined average yield was lower than the average yield of rainy season sorghum by about 6.4%. Among the study districts, Latur and Nanded occupy the top two positions with more than 100,000 ha each under rainy season sorghum. There is a great variability in the productivity of rainy season sorghum in the study districts (see Table 3). The remaining five districts recorded less than 50 thousand tons of production each and Beed was at the lowest rung of the production ladder.

Of all the major districts growing rainy season sorghum in Maharashtra, Jalgaon reported the highest yields while Latur commanded the highest area. The growth trends in the productivity of the rainy season sorghum in these two districts were estimated for the period between 1990 and 2010. The trend equations exhibited poor fits, explaining hardly 9-13% variation in the productivity. The productivity showed a slightly upward trend in Jalgaon while it indicated a negative growth in Latur district.

3. Historical Development and Diffusion of Rainy Season Sorghum Improved Cultivars

Sorghum research has received the major attention of the Indian Council of Agricultural Research (ICAR) right from the mid-1960s. It was initially a part of the Project on Intensified Research on Cotton, Oilseeds and Millets (PIRCOM) for a few years but was later brought in 1970 under the All India Co-ordinated Sorghum Improvement Project (AICSIP), the headquarters are located at Hyderabad, which was later

1. 2008-10 triennium data was used as a basis for identification of sample districts in the study.

Table 3. Area, production and productivity of rainy season sorghum in study districts.

District	Area, 2008-10 ('000 ha)	Production, 2008-10 ('000 tons)	Productivity, 2008-10 (kg ha^{-1})
Jalgaon	80.33	173.39	2086
Satara	45.63	76.63	1681
Akola	50.03	75.78	1535
Dhule	23.37	32.45	1353
Hingoli	39.03	43.66	1117
Parbhani	62.43	68.4	1095
Latur	121.93	132.43	1079
Amravati	45.93	47.01	1017
Sangli	72.77	70.7	916
Nanded	120.97	110.17	912
Beed	33.6	30.15	898
Yavatmal	71.5	53.97	752
Osmanabad	62.17	37.37	616
Sum of 13 districts	829.69	952.11	1148
Maharashtra	981.00	1198.00	1226
Share of 13 districts in Maharashtra (%)	84.60	79.50	93.60

renamed as National Research Centre for Sorghum (NRCS) and then to Directorate of Sorghum Research (DSR). Recently it has been now changed to 'Indian Institute of Millets Research' (IIMR). The project opened a sub-center at Solapur to work on postrainy sorghum. AICSIP developed and released several improved varieties and hybrids to achieve breakthrough in sorghum production. Maharashtra being the most important state in India for sorghum production, at least three out of four agricultural universities in the state has a major focus on sorghum research. These universities - Marathwada Agricultural University (MAU), Parbhani; Mahatma Phule Krishi Vidyapeeth (MPKV), Rahuri; and Punjabrao Krishi Vidyapeeth (PKV), Akola have major areas under sorghum in the areas under their jurisdiction and they are engaged in the development of improved cultivars and agronomic practices suited to their regions in collaboration with DSR. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) was set up in 1972 with its main center at Hyderabad and it has the mandate to preserve the entire global collection of sorghum germplasm, work on its improvement and develop improved varieties and hybrids in collaboration with DSR, State Agricultural Universities (SAUs) and Private and Public Sector seed companies. A number of varieties and hybrids were developed by all these entities enlarging the choice set available to the farmers.

In India, CSH 1 was the first hybrid developed and released in 1964 for rainy season cultivation. It was dwarf, early maturing with bold seed but was susceptible to shoot fly and grain mold diseases. Another hybrid, CSH 5 was released in 1975, again for rainy season. It had medium duration, medium height, thick juicy stem and medium bold seed. It had a yield potential of 3.4 tons of grain per ha as against the 3.0 tons ha^{-1} potential of CSH 1. It was less susceptible to grain deterioration and leaf spot diseases. It was soon followed by CSH 6 in 1977, which was suitable to drier areas due to early maturity, same yield potential as CSH 5, resistance to grain deterioration and tolerance to leaf spot diseases. CSH 9 was developed and released in 1983 with a higher yield potential of 3.9 tons ha^{-1}, medium height, bold round seed, large semi-compact head, less susceptible to grain molds and resistance to leaf diseases. These hybrids have become immensely popular with the farmers. Besides these hybrids, improved varieties like CSV 10 (SPV 346) and CSV 15 from DSR; CSV 11 (SPV 35) and CSV 13 (SPV 475) from ICRISAT; SPV 462 from Coimbatore and PVK

801 from Parbhani found their own niches in sorghum growing areas of the country. These early released hybrids and varieties caused a jump in productivity of sorghum in the country.

Initially, it was public sector agencies such as National Seeds Corporation, Tarai Development Corporation and State Seed Corporations which organized the production of the seeds of released varieties, as well as procured, processed and marketed them in the areas where they are in demand. The Govt. of India enacted seed law during that period which allowed private sector investments in seed research, multiplication and marketing. As a result, gradually, private seed companies, particularly research-based companies, established themselves and dominated the market, gradually pushing public sector companies into a marginal role. In the last twenty years, multi-national companies have also entered the scene and acquired companies to grow both organically and inorganically. Private sector companies acquired parent materials from public sector research bodies, developed hybrids and varieties and have made them far more accessible to distributors and dealers, and finally to the farmers. The hybrid proceed with their superiority over varieties and hence became popular with farmers.

The hybrid seeds need to be replaced every year and the private sector is well equipped to deliver. Farmers have given up their traditional seed systems (growing varieties and saving part of harvest seed) and are looking forward to buying the latest, better-proven hybrids each year. Several private sector seed companies have joined the Hybrid Parents Research Consortium (HPRC) of ICRISAT and are receiving the parental lines - 'A' lines, 'B' lines and 'R' lines to accelerate their breeding programs. They match their own hybrids and identify the best ones after testing. These hybrids are marketed on their brands and charge premium prices sold to the farmers. They are able to build reputation and trust through their demonstrations and marketing strategies and, of course, quality! As a result, the market is flooded with a number of research-based proprietary hybrids which makes it quite difficult some time to the farmers to choose from!

3.1 Sorghum cropping systems

Sorghum in India is grown both as a sole crop as well as an intercrop to optimize resource use and give a higher land equivalent ratio. In some areas, sequence crops are also grown to obtain the highest returns possible in an area.

3.1.1 Intercropping systems with sorghum

Sorghum in the rainy season is most commonly intercropped with pigeonpea in varying proportions. While scientists recommend intercropping of sorghum with pigeonpea in 2:1 proportion, farmers grow them in 4:1 or 6:1 proportion also. Sorghum-pigeonpea intercropping is found to be the most desirable, profitable and stable intercropping system. It is also intercropped in the recent years with soybean, green gram and black gram in the rainy season and with safflower or chickpea in the postrainy season.

3.1.2 Sequence cropping with sorghum

In some areas, sorghum is taken after the harvest of short duration pulses like green gram and black gram as a late rainy season crop. Sequence cropping of sorghum-safflower or sorghum-chickpea is sown if the soils are heavy and have water retention capacity. It is recommended to harvest sorghum at physiological maturity and immediate sowing of seeds of safflower or chickpea in between the stubbles of sorghum. Deep harrowing helps in removal of stubbles and in the establishment of sequence crop.

3.1.3 Ratooning of sorghum

The ratoon crop of sorghum can be raised to harvest more biomass in a limited time by providing irrigation and plant protection. Growing ratoon crop of CSH 5 hybrid was most popular in Jalgaon district of Maharashtra state. Grain harvested from ratoon crop is locally marketed as "*durri*" at higher market prices. Normally, sorghum is grown either in the rainy season or in the postrainy season. Occasionally though, it is also grown as a summer crop. Sweet sorghum and high-energy sorghum varieties are also rarely grown.

3.2 Improved technology over time

Due to the dominance of rainy season in the country, sorghum crop improvement research in India, in general, was skewed towards rainy season till late 1990s. Since then, however, there has been a tremendous shift in sorghum cropped area from the rainy to the postrainy season. Because of stiff competition from other rainy season crops and lack of favorable policy support from government, the area under rainy season sorghum is declining rapidly in India, especially in Maharashtra state. Thanks to good grain quality coupled with food consumption preferences, postrainy sorghum area is stable and sustaining its production. There is increased emphasis on postrainy season crop improvement and there is a long way to go.

Besides the hybrids and varieties developed by IIMR and ICRISAT, the state agricultural universities at Parbhani and Akola have also developed some varieties suitable for rainy season cultivation. IIMR developed CSH 13K, CSH 16 and CSH 17 hybrids mainly for the rainy season targeting Maharashtra, Tamil Nadu and Andhra Pradesh. The University of Agricultural Sciences, Dharwad developed CSH 10, while ICRISAT developed CSH 11 hybrid. PKV, Akola developed CSH 14, while JNKVV, Indore developed CSH 18. Among the varieties, MAU, Parbhani developed PVK 801 and PVK 809 for the rainy season. Private seed companies in collaboration with ICRISAT-HPRC (Hybrid Parents Research Consortia) program also developed several hybrids for rainy season. More than 50% coverage in the total area planted under hybrids in the country is bred from ICRISAT lines or from their deliverables. In particular, JKSH 22, VJH 540, MLSH 296, GK 4009 and GK 4013 are hybrids that are most popular and widely adopted in India, especially in Maharashtra (Belum et al. 2005).

Many of these hybrids and varieties developed by public sector research institutions did not survive very long due to lack of sustained efforts in seed production, procurement, processing and marketing. But those developed by the private sector companies are branded and therefore recognized by farmers due to their attractive packaging and marketing strategies. In the market survey preceding the farmers' survey, it was noted that the private sector hybrids are dominating the rainy season market. Only a few early maturing hybrids from the public sector are still to be found in the market. The most promising rainy season hybrids released between 1970 and 2011 in Maharashtra state are summarized in Table 4 along with their pedigree and source of genetic material.

3.3 Policy bias over period of time

In general, coarse grains were the staple grains produced and consumed in the rainfed areas of the country. After independence, however, there was a massive drive to build irrigation projects wherever possible. Since it was decided by the union and state governments not to recover the capital costs of these projects from the beneficiaries, demands came from the people of all regions to build more and more of these projects. The lands receiving water from irrigation projects appreciated in value, subsequently reached higher productivity levels and received higher rents in the form of lease values, all because of public investments that were never recovered from the beneficiaries. In contrast, rainfed lands, on which coarse cereals such as sorghum are grown, never received the benefits of public investments and remained low productive areas (Rao 2006; also see Box 1). Once irrigation facilities developed, cropping patterns changed from coarse cereals like sorghum to fine cereals like rice, wheat etc.

In case of irrigated areas, marketable surplus developed in crops like rice and wheat due to higher and stable yields. The surplus generated was procured and stored by the Food Corporation of India (FCI) and state civil supplies corporations. When the government introduced public distribution system (PDS), the rice and wheat procured were distributed at subsidized prices. It became possible to access fine cereals at much lower prices than coarse grains like sorghum in the Public Distribution System (PDS). The public distribution system distorted the price ratios in the market and the consumption of coarse grains was substituted by that of fine cereals. The bias was also implicit in the minimum support price (MSP) policy.

In the initial years of price policy, the minimum support price announced for sorghum was about the same as that announced for coarse variety of paddy, which continued up to 1982-83. The difference between the MSP of coarse variety of paddy and sorghum kept on widening over the years, however. They were

Box 1: A study conducted by KPC Rao (2006) in Andhra Pradesh estimated the levels of input subsidies accessible to farmers in rainfed and irrigated areas between 1994-95 and 2002-03. The total weighted average subsidy received in 1994-95 was estimated at Rs 1940/ha. It went up to Rs 3578/ha by 2002-03. It indicated a remarkable increase of 84% over a period of eight years.

During 1994-95, an irrigated hectare in the state received an average subsidy of Rs 4304 as against a mere Rs 326 in case of a rainfed hectare. By 2002-03, the gap between them had widened further. In 2002-03, an irrigated hectare received a subsidy of Rs 8566, while a typical rainfed hectare received only Rs 356 as input subsidy. The percentage increase in subsidy per hectare was 99% in the case of irrigated agriculture, while it was only 9% in the case of rainfed agriculture. The input subsidies received by an irrigated hectare was 13 times that of a rainfed hectare in 1994-95. This ratio grew to 24 times by 2002-03 on account of a rapid increase in power subsidies.

The study also calculated that nearly 46% of the total subsidies were accounted for rice alone in the state. Cotton and groundnut followed distantly with their shares at 5% and 4% respectively. Dryland crops such as sorghum, pearl millet and finger millet accounted for less than 1% of the total subsidies.

brought to the same level only in 2012-13. For nearly 30 years, farmers growing sorghum and other coarse grains were discriminated against by the minimum support price policy (see Figure 8).

MSP was only part of the story. Coarse grains like sorghum were procured rarely, if at all, by the Food Corporation of India even when the market prices have fell below the minimum support prices. Procurement of rice and wheat, on the other hand, was a routine operation in surplus states, both when their market prices were above the MSPs as well as when they fell below the minimum support prices announced. A few reasons were advanced for non-procurement of coarse grains like sorghum. One, that there was no consistent marketable surplus in case of sorghum, as its production was subject to the vagaries of monsoon. Another reason was that coarse grains like sorghum was considered are difficult to store and would deteriorate in quality much faster than rice and wheat. This disadvantage could have been off-set by research into storage and innovations in processing. Coarse grains were not included in the Public Distribution System (PDS) till last year, when the National Food Security (NFS) Act was passed.

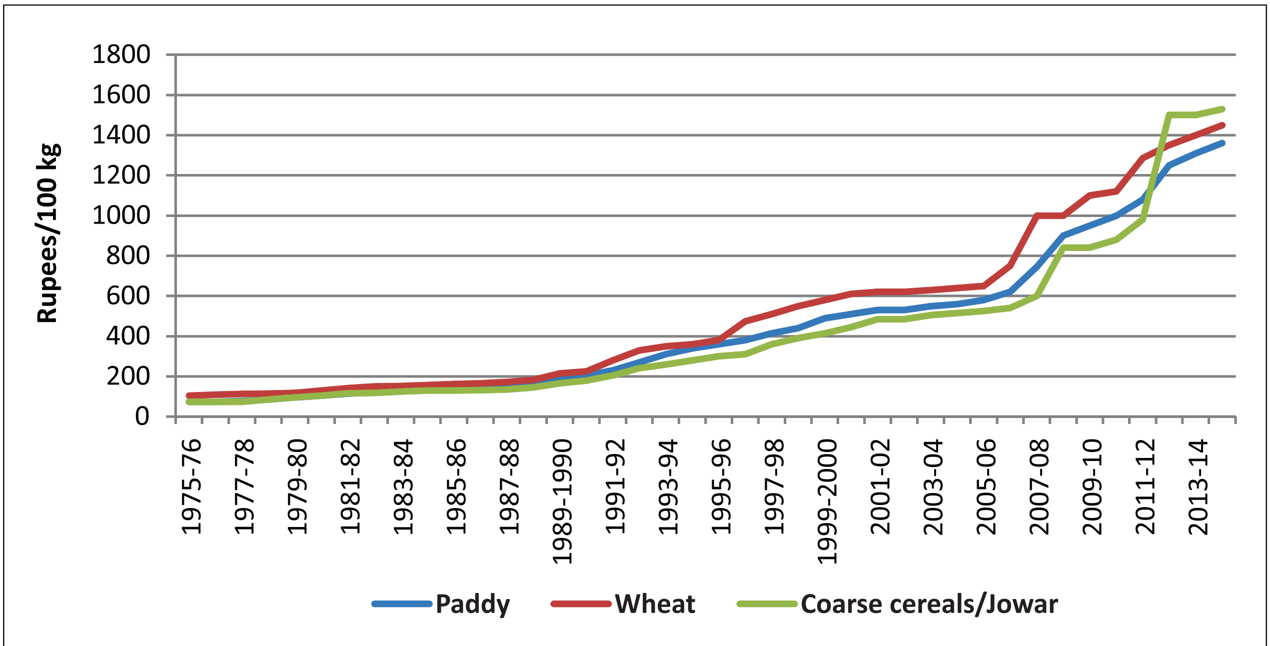


Figure 8. Minimum support prices (MSP) of fine and coarse cereals (Rs/100 kg) in India.

Table 4. Prominent rainy season sorghum releases in Maharashtra, 1970-2011.

Varieties/hybrids	Pedigree	Release year	Developed by
CSV 6	IS 3922 X Aispuri	1974	
CSV 2	IS 3922 X Karad local	1975	MAU, Parbhani
CSV 3	S 2954 X BP 53	1976	
SDM-9		1976	MPKV, Akola
SPV 297	CS 3541 X IS 3924	1984	MAU, Parbhani
CSV 11	SC 108-3 X CS3541	1985	
CSV 13	(IS 12622 X555) X S 3612 X 2219B X E35-1	1988	
SAR 1	555 X 168	1988	
PVK 801/Parbhani Sweta	Selection From ICRISAT population GD 34-5-5-3	2000	MAU, Parbhani
PVK 809	PVK 801 X SOV 881	2004	MAU, Parbhani
CSV 23	SPV 861 X SU 248	2008	
CSV 20	SPV 946 X kharif h89-246	2009	
Hybrids			
CSH 3	2219A X IS 3691	1970	
CSH 4/PSH 1	1036A X Swarna	1973	MAU, Parbhani
MSH-51		1982	Mahyco Pvt Ltd
CSH 9	296 A X CS 3541	1983	NRCS
CSH 11	296AX MR 750	1986	
AKSH-73	296A X R73	1990	MPKV, Akola
CSH 14	AKMS14AX AKR 150	1992	MPKV, Akola
CSH 16	27AXC43	1997	
MLSH-296 (Mahalaxmi)	309 A X SB-1085	1997	
CSH 18	IM 9AX Indore 12	1999	
JKSH 22 (JK Jyothi)	323 A X SB-1085	1999	J K Agri-genetics
NJH-40 (Ratna)		1999	Nirmal seeds
MAHABEEJ-7 (MBSH-7)	314 A X SB-1085	2000	MSSDC, MH
SPH-840	MS 70A X ICSR 89058	2000	MPKV, Akola
ProAgro-8340		2001	Bayer Crop Science
Ajeet 997		2002	Ajeet Seeds
PAC 537		2003	Advanta Pvt Ltd.
CSH 21	MLSA 848 X MLR 34	2005	Mahindra Pvt Ltd.
CSH 23	MS 7A X RS 627	2005	
CSH 25	PMS28AXC43	2007	MAU, Parbhani
SPH 1567	28A XC43	2007	PKV, Akola
PAC 501	5101 F X 501 M	1998*/2007	Advanta Pvt Ltd.
Hytech 3201		2007	Hytech Pvt Ltd.
NJH 1175		2011	Nirmal Seeds
NSH 18		**	NU Genes
NSH 27		**	Sona (Nuziveedu)

*Marketed since 1998 but formally notified in 2007 ** Exact marketed year not known

Theoretically, a consumer can now demand coarse grains like sorghum at Rs 1 kg^{-1} but it is not known whether the government will be able to fulfil this promise as procurement operations are yet to begin in case of coarse cereals like sorghum.

The study of market prices of cereals in the post-harvest period revealed that the prices of wheat were consistently higher than those of other cereals (see Figure 9). Paddy prices also, by and large, was higher the prices of sorghum and pearl millet, barring one or two exceptional years.

These policy biases by governments inhibited growth in sorghum production. In contrast, the production of rice and wheat increased several-fold as they were able to ride on the crutches of capital and production subsidies as well as consumption subsidies given to the poor under the PDS. Had the capital costs of irrigation projects been fully recovered from the beneficiaries, the profit surplus earned in case of paddy and wheat would have been much lower. Similarly, if rainfed areas had received production subsidies at the same level that the irrigated areas and crops received, reduction in areas under coarse grains would not have been as dramatic as it was during the last four and half decades. Had coarse cereals like sorghum been treated at par with rice and wheat in the public distribution system and not been discriminated against in the fixation of minimum support prices, they would have retained substantial areas under them. Had coarse cereals received the same kind of procurement support as rice and wheat, sorghum would not have lost its area as rapidly as it did. All these adverse policies have done much more harm to sorghum farmers than natural calamities such as droughts and excess rains. The hard work of sorghum researchers and farmers would have received greater recognition if there had been a balance in public policies. Normally, policy is expected to come to the rescue of the disadvantaged. In this case, they had the opposite effect: they have aided the replacement of coarse cereals by fine cereals. And it also meant robbing poor farmers of rainfed areas and fattening the rich in well-endowed areas.

3.4 Sorghum supply and demand in India

In Asia, sorghum area dropped from 20.4 to 8.7 m ha over the 32-year period (1980-2012). However, its productivity increased from 935 kg ha^{-1} to 1165 kg ha^{-1} during the same period. As a result of drop in area, sorghum production fell from 19.1 to 10.2 m tons during the study period. Because of the dominant position of maize, sorghum accounted for only a 4% share in the coarse grain production of Asia. In India, the area dropped by 54% from 16.3 m ha in 1980-82 to 7.5 m ha in 2009-11. But, its production fell by only 38% in the same period from 11.1 to 6.9 m tons. This was due to improved productivity that went from 681 to 924 kg ha^{-1}. The trends of falling area and production of sorghum are continuing in India even after

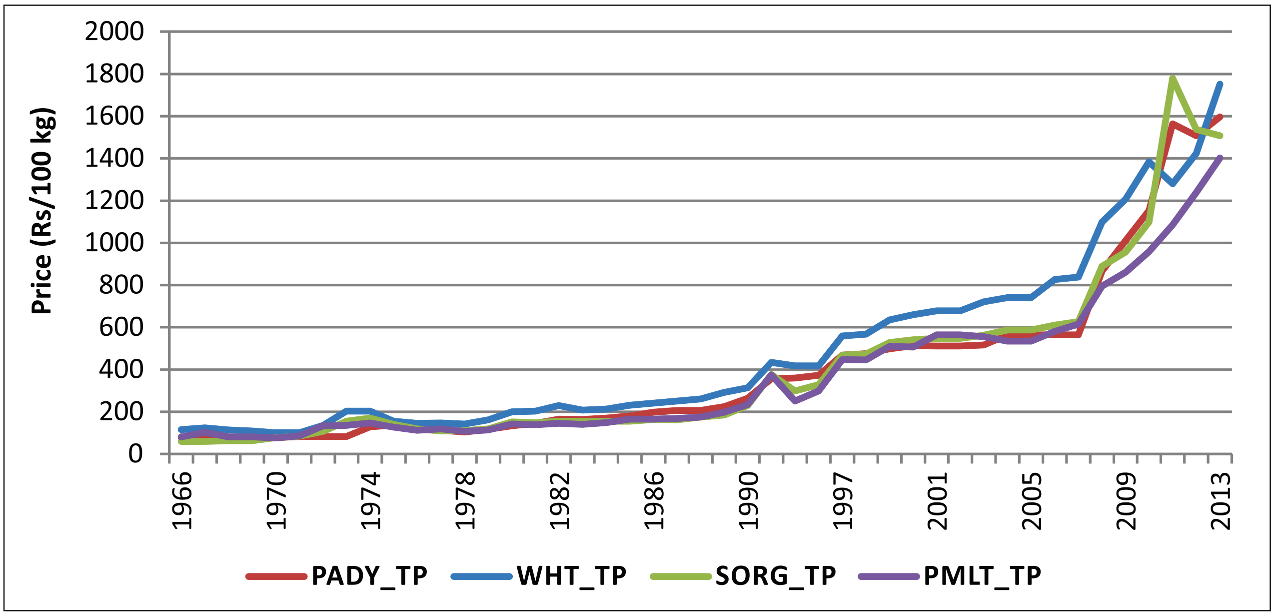


Figure 9. Farm harvest prices (FHP) among cereals in Maharashtra (Rs/100 kg).

2011. So, its supply is further projected to decrease in the future also. It may be argued that the supply is falling in response to its falling demand. Had the demand been increasing, its relative prices would have increased and supply would have responded to them. However, IFPRI-IMPACT (International Food Policy Research Institute – International Model for Policy Analysis of Agricultural Commodities and Trade) model projections provide a ray of hope to India (Nedumaran et al. 2013[2]). They predict a slower reduction in sorghum area and an upward trend in sorghum production between 2010 and 2050 (see Figure 10). There are concerns about global warming and hot weather tolerant crops like sorghum may come back in to contention if global warming goes on unabatedly.

According to the IFPRI-IMPACT model, the demand for sorghum is expected to increase from 8 m tons in 2010 to about 10 m tons in 2050. The shares of feed and other uses are projected to increase, albeit slowly (see Figure 11 and Nedumaran et al. 2013).

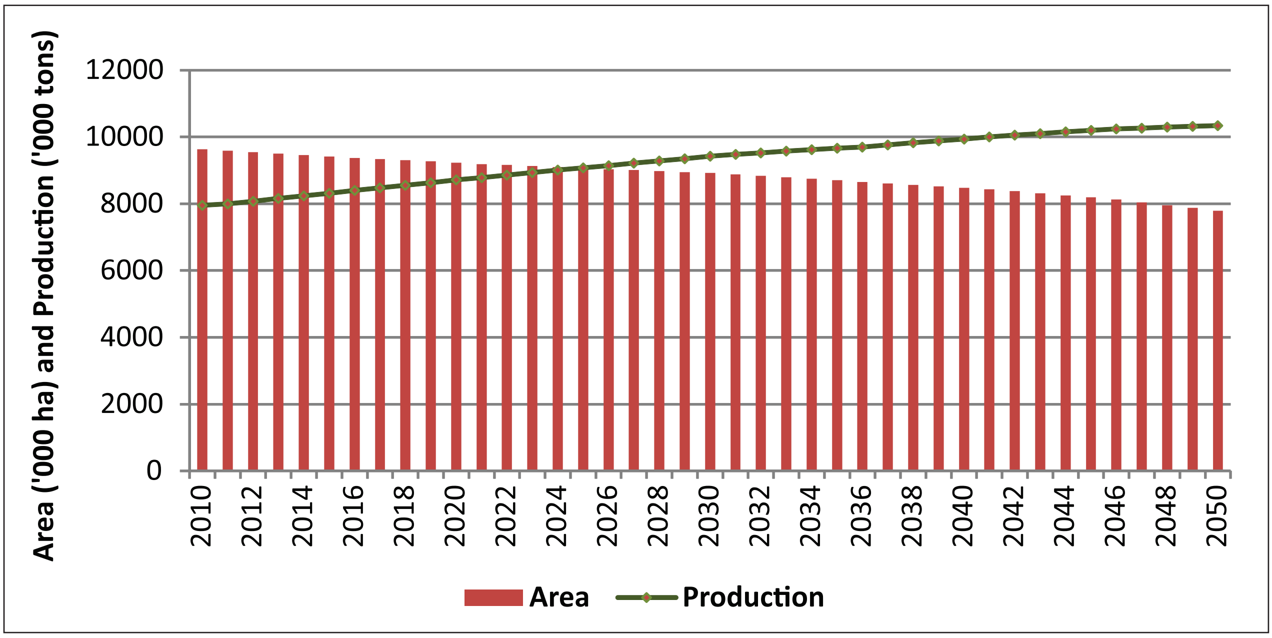


Figure 10. Sorghum area and production in India, 2010-2050.

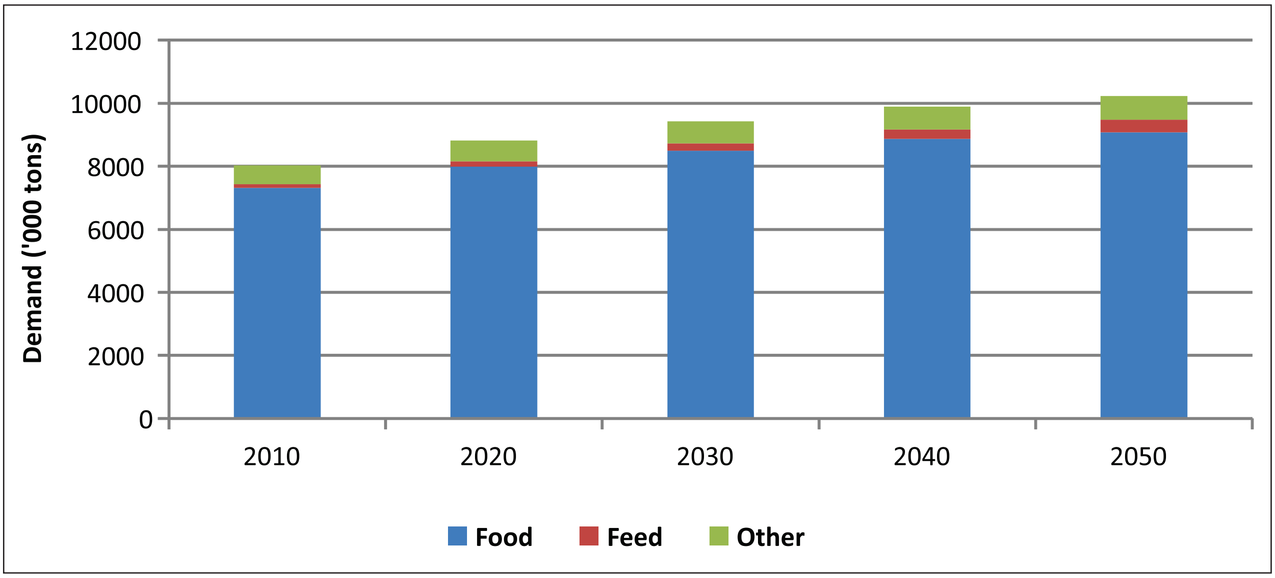


Figure 11. Sorghum food, feed and other demand in India, 2010-2050.

2. See more detail at Nedumaran et al. 2013

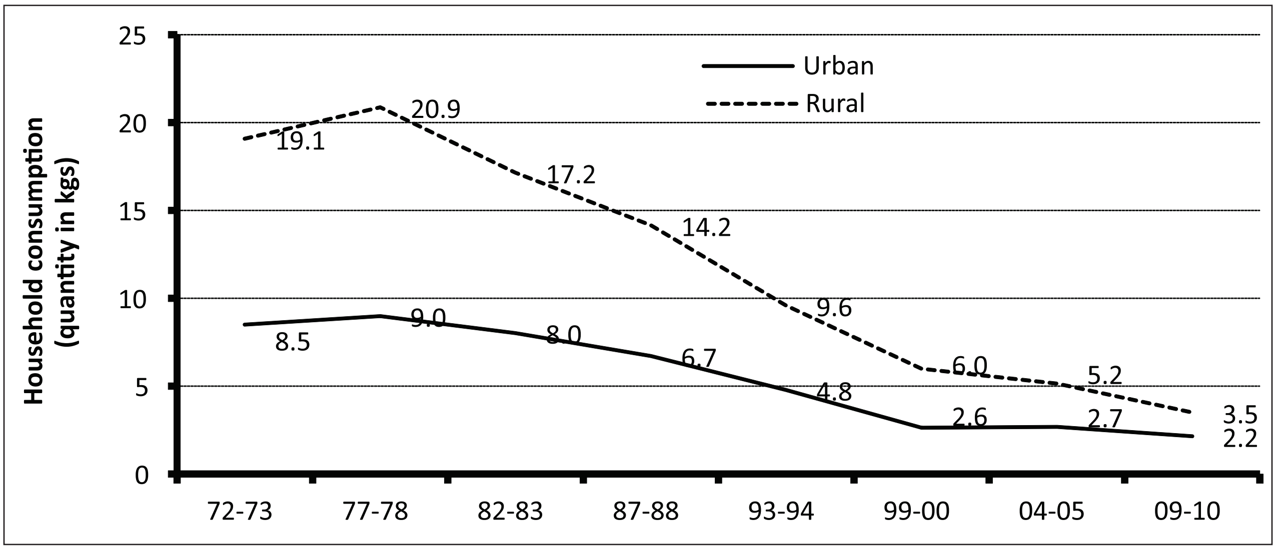
3.5 Per capita consumption

Since India does not trade with other countries, India's estimated consumption of sorghum can be equated to its production. The alternate uses of sorghum as a cattle or poultry feed or as a raw material for alcohol or starch are at present insignificant and almost the entire production of grain is used for purposes of food. However, these alternate uses may assume importance in the future.

Food use in different regions and in India[3]

Sorghum continues to be an important staple in Africa and in regions of India where it is traditionally consumed. Food consumption of sorghum in Africa doubled between 1980-82 and 2007-09 from 8 to 17 m tons. The per capita consumption of sorghum is highest in Africa. Besides, even with an increase in population between 1980 and 2009, per capita consumption increased from 17 kg/person/year in 1980-82 to 19 kg/person/year in 2009. In Asia, rising incomes, urbanization, and changing consumer preferences have led to a sharp decline in food consumption of sorghum from 15 to 8 m tons in 2007-09. Per capita consumption too declined sharply from 5.8 to 2.1 kg/capita/annum.

In India sorghum is a traditional cereal staple but it has been declining in popularity and importance over time, particularly in urban areas. An in-depth analysis of the consumer survey data for India conducted by the National Sample Survey Organization (NSSO) revealed that the annual per capita consumption of sorghum declined sharply between 1980 and 2010 in both urban and rural areas (Figure 12). This decline is largely attributable to the fact that as incomes increase, fine cereals are substituted for sorghum. Government policies providing subsidized fine cereals like rice and wheat have further exacerbated this situation. However, since the mid-1990s, per capita sorghum consumption while continuing to decline has slowed down compared to the sharp declines in the 1970s and 1980s. The largest decline in consumption has been in the states of Andhra Pradesh and Madhya Pradesh where the availability of subsidized staples such as rice in Andhra Pradesh and wheat in Madhya Pradesh has contributed to the increased substitution of sorghum. In the major growing regions of the states of Maharashtra and Karnataka, where sorghum had a major share in the consumption basket in the 1970s, it is still able to compete in the cereal consumption basket because of existence of strong preference for sorghum in the daily food requirement (Basavaraj and Parthasarathy Rao 2012).



Source: Compiled from Level and Pattern of Consumer Expenditure, NSSO 62nd Round, 2009-10

Figure 12. Annual per capita consumption of sorghum in urban and rural India (kg).

3. See Parthasarathy Rao P and G Basavaraj (2013) for more details

There are, however, differences in the utilization of rainy and postrainy season sorghum in India. The decline in per capita food consumption of sorghum at the all-India level is mainly due to decline in production of rainy season sorghum while the availability of postrainy season sorghum has more or less remained constant (see Figure 13). Bulk of the postrainy season sorghum grain is used for food since it is of superior quality with a bold grain, lustrous white color and sweeter taste. Postrainy season sorghum grain prices are higher by 20-40% compared to rainy season sorghum, thus making it uneconomical for alternative uses such as poultry feed and alcohol manufacture compared to other close substitutes. Besides its use as a staple at household level, small quantities of postrainy season sorghum are used in the processed food industry (Basavaraj and Parthasarathy Rao 2012).

Further disaggregation of NSSO (National Sample Survey Organization) consumption data by expenditure classes reveals that sorghum is an important crop for the nutritional security of the poor in India. The low income consumers (about 50% of the population in rural and urban areas each) account for 52% and 67% of sorghum consumption in rural and urban areas of India respectively (Table 5). Their per capita consumption is also the highest among the three income groups. Small quantities of sorghum are also being used by the food manufacturing industry for making biscuits, breads, noodles and cakes. With increasing awareness about the nutritional properties of sorghum, the demand for such products is increasing from a low base.

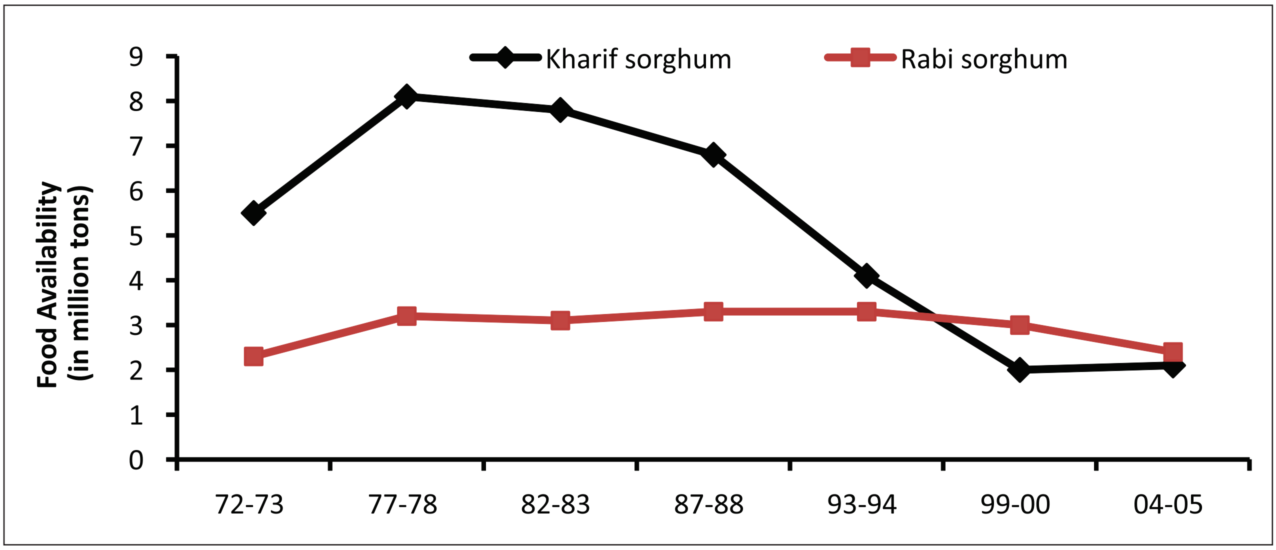


Figure 13. Availability of rainy season and postrainy sorghum for food use in India.

Table 5. Consumption of sorghum by income class, 2009-10.

Expenditure category	Consumption ('000 t)	Consumption (%)	Per capita consumption (kg yr^{-1})	Population (%)
Rural average consumption by expenditure category				
Low (Less than ₹ 765 (USD14.98) per month)	1,447.6	52.2	4.75	50
Medium (₹ 765-1477 (USD14.98-28.93) per month)	1,106.9	39.9	3.64	40
High (Greater than ₹ 1477 (USD28.93) per month)	221.1	8.0	1.45	10
Urban average consumption by expenditure category				
Low (Less than ₹ 1307 (USD25.60) per month)	414.5	67.3	3.67	50
Medium (₹ 1307-3166 (USD25.60-62.02) per month)	172.0	27.9	1.52	40
High (Greater than ₹ 3166 (USD62.02) per month)	29.1	4.7	0.52	10

Source: Compiled from Level and Pattern of Consumer Expenditure, NSSO 62nd Round, 2009-10

At the all-India level, the per capita consumption of sorghum in rural areas during 2009-10 was as low as 4.75 kg/annum in the low income households; 3.64 kg/annum in the middle income households; and 1.45 kg/annum in the high income households. The per capita consumption levels were much lower in the urban areas: 3.67 kg/annum in low income households; 1.52 kg/annum in middle income households; and 0.52 kg/annum in high income households.

Feed and other uses

In India, sorghum grain is used as poultry feed. Its popularity in this use pattern has been increasing, with the poultry farms substituting sorghum for maize depending on the relative price of the two crops. Sorghum is generally substituted to the extent of 25-50% of maize ration if its price is 10-15% lower than maize price. The poultry industry in India is growing at 5% per annum and the associated demand for sorghum feed is expected to increase in the near future. It is also expected that sorghum non-food uses will increase in the future, largely owing to renewable energy legislation in most countries that mandates the mixing of biofuels to meet emission reduction cut offs, and which has resulted in a diversion of maize to ethanol production lowering its availability for feed use.

Fodder

The use of sorghum as a dual-purpose crop is restricted largely to the developing countries of Africa and Asia, where besides grain, the straw/stalk is an important component of livestock feed. Sorghum stover is also considered to be more nutritious with a higher digestibility coefficient compared to rice and wheat stover. In India, sorghum stover is stored and constitutes an important feed for livestock in the dry months of the year when other feed sources are scarce.

In India, the increased demand for livestock products due to increasing incomes and urbanization is driving the derived demand for fodder and feed from different sources. For sorghum, this is reflected in the faster increase in sorghum straw prices compared to grain. The grain to fodder price ratio fell from 6:1 in 1980 to 3:1 by 2005. Consequently, the value of fodder in total value of sorghum crop production also increased from 20% to 40% by mid-2000 (Kelley et al. 1993; Parthasarathy and Hall 2004). In Rajasthan, the value from sorghum fodder was nearly equal to the value from sorghum grain in 2009-10. This trend is expected to continue in the near future with feed demand estimated to increase to 855 million ton in India by 2020 driven by the livestock revolution (Dikshit and Birthal 2010).

3.6 Livestock population census in Maharashtra

The livestock census data for both Maharashtra as well as for India illustrate that the livestock numbers increased till 1997 but declined by 2003 (see Table 6). The number of cattle, which are reared for both draft and milk purpose increased in Maharashtra between 1992 and 1997, but decreased during the next six years period. But the number of buffaloes did increase slowly but steadily in Maharashtra. These trends are more prominent at the all-India level. Cattle population dwindled steadily between 1992 and 2003, while the population of buffaloes, which are reared for milk, showed an increasing trend. As the livestock population decreased, the requirement for fodder also decreases, which acts as a dampener on the acreages of sorghum and pearl millet, which are grown by the farmers for both grain and fodder.

Table 6. Pattern of livestock census in Maharashtra and India (‘000).

Census	Maharashtra (‘000)				India (‘000)			
year	Cattle	Buffaloes	Others	Total	Cattle	Buffaloes	Others	Total
2003	16303	6145	14315	36763	185181	97922	201898	485001
1997	18072	6073	15486	39630	198882	89918	196582	485381
1992	17446	5447	13504	36397	203063	83522	181374	467959

3.7 Long-term supply and demand elasticities of sorghum

The literature survey did not find estimates appropriate to sorghum, both on the supply as well as on the demand side. Praduman Kumar et al. (2011) estimated the income (expenditure) elasticity of food, using QUAIDS (Quadratic Almost Ideal Demand System) model. They estimated the expenditure elasticity of cereals at the aggregate level as 0.187. It was higher at 0.514 for the very poor class; and it decreased to 0.424 for the moderately poor; and further decreased to 0.312 for the non-poor (lower income) consumers. In case of non-poor (higher income), the expenditure elasticity turned negative (-0.095). With the same model, they estimated the uncompensated own price elasticity of cereals as -0.031 for the aggregate group of consumers. The own price elasticity was higher at -0.309 for the very poor group. Its absolute value started falling for the moderately poor (-0.242); to -0.150 for non-poor (lower income); and to -0.006 for non-poor (higher income). The inelastic nature of demand for cereals is highlighted by these estimates. When they used the Food Characteristic Demand System (FCDS) model, the income elasticity for coarse cereals was estimated at -0.125 for all consumers. It was -0.123 for very poor group, -0.154 for moderately poor group, -0.141 for non-poor (lower income) group, and -0.095 for non-poor (higher income) group. Thus, the income elasticity of cereals was found to be positive but decreased with the increase in income. However, in case of coarse cereals, the income elasticity was negative for all income groups, signifying that they are treated as inferior goods by all consumers. Using the same FCDS model, they estimated uncompensated own price elasticity for coarse cereals. These results were in conformity with the results obtained for cereals with QUAIDS model and highlighted the inelastic nature of demand for cereals. The price elasticity of demand was moderate at -0.194 at the aggregate level. The elasticity of demand turned more inelastic with the increase in income level. It was -0.333 for very poor group, -0.281 for moderately poor group, -0.196 for non-poor (lower income) group and -0.109 for non-poor (high income) group.

Ganesh Kumar et al. (2012) estimated the elasticity of food expenditure for superior cereals in India. The expenditure elasticity was -0.21 for rice and -0.13 for wheat, showing that they are also tending to be inferior goods. They also estimated elasticity for un-irrigated crop acreage model using non-linear Seemingly Unrelated Regression Estimates (SURE). The coefficients were 0.9857 for rice, 1.1359 for wheat and 1.0704 for maize, by using relative price as their explanatory variable. But the right measures could be obtained by regressing acreage against own price and not against relative price. Due to paucity of literature with respect to demand and supply elasticity of sorghum, some realistic assumptions have to be made for making the welfare estimates due to technical change.

4. Sampling Framework and Methodology

As indicated in the previous chapters, the major objective of the present study was to assess the extent of adoption of rainy sorghum improved cultivars in the state and quantify its impact on farm yields and household incomes. For this purpose, the study design was carefully planned to cover more geographical area rather than in few districts. So, the following systematic sampling efforts were used to draw a more geographically representative sample in the state. The study was carried out during 2013 and the household data was collected with reference cropping year 2012-13.

The areas under rainy season sorghum from 2006 to 2011 in Maharashtra were averaged and are presented in Table 9 for the important districts growing rainy season sorghum. Among the districts of Maharashtra, 13 districts had major areas under rainy season sorghum (see appendix 1). Latur and Nanded districts have about 120 thousand hectares each. Jalgaon, Sangli, Yavatmal, Osmanabad, Parbhani and Akola have areas ranging between 50 and 80 thousand hectares. Amravati, Satara, Hingoli, Beed and Dhule have areas ranging from 23 to 46 thousand hectares under rainy season sorghum. These 13 districts together accounted for 85% of the rainy season sorghum area in Maharashtra and they contributed 80% of sorghum production in the rainy season (see Figure 14).

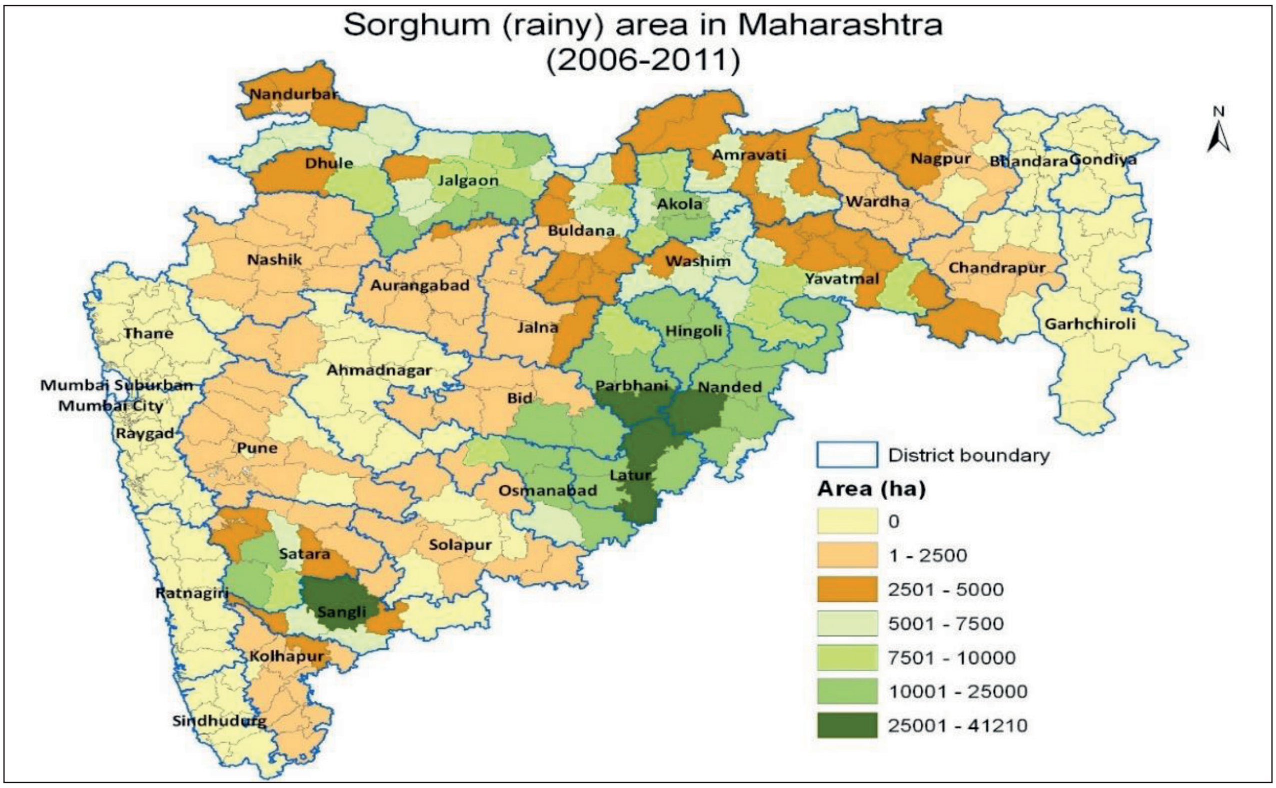


Figure 14. Distribution of rainy season sorghum in Maharashtra state, 2006-2011.

4.1 Sampling frame

Based on the discussions held with the experts and the suggestions received from them, it was decided to cover only rainy season sorghum in Maharashtra state. Many cultivars have been released by both public and private organizations and the extent of adoption is at its peak (> 98%). In case of postrainy season sorghum, the targeted cultivars are very few and the extent of adoption under new varieties is still low. Maldandi (M35 1), a local cultivar, continues to dominate and occupies nearly 60% of postrainy sorghum area in Maharashtra. So, the present adoption survey focused more on rainy season sorghum improved cultivars. Instead of sorghum-growing districts, tehsils were identified as a primary sampling unit for achieving a representative sampling framework for the study. The tehsil-wise distribution of crop and the corresponding cut-off levels and their representation are summarized in Table 7.

Table 7 gives the distribution of tehsils according to the concentration of rainy season sorghum area in them. There are 250 tehsils in Maharashtra with some area under rainy season sorghum and if all of them are taken as the population, 100% area under rainy season sorghum will be represented. As a second option, if only the tehsils with more than 1000 hectares under rainy season sorghum are considered, there will be 169 such tehsils and they will together have 98.3% area. In the next option, by considering only the tehsils with more than 3000 hectares area under rainy season sorghum, 133 tehsils will be included in the population and they will together represent 92% of the total area. The last option in the

Table 7. Coverage of rainy season sorghum in Maharashtra by tehsil.

Tehsil-level sorghum cut-off area (ha)	No. of tehsils growing sorghum in the state	% coverage
> 0 ha	250	100.0
> 1000 ha	169	98.3
> 3000 ha	133	92.0
> 5000 ha	91	77.2

table relates to only those tehsils with more than 5000 hectares giving 91 tehsils which will together have 77.2% of the rainy season sorghum area in the state. It was decided to take them as the population from which a sample of 20 tehsils drawn to represent about 77.2% rainy season sorghum area in the state. With the binding limitation of budget and time, the adoption tracking was done in the 20 sample tehsils through primary survey using probability proportion to cropped area method. Based on the randomization procedure, the sample tehsils were selected for rainy season sorghum in Maharashtra state and presented in Table 8 (see Appendix 2 for more details). From each of these tehsils, three villages were selected and six farmers growing sorghum in the rainy season were picked up randomly from each of the 60 villages, thus yielding a sample of 360 households from 13 districts of Maharashtra state. Marathwada (MTW) region, which has the maximum area under rainy season sorghum, received a 50% weight in the post stratification of sample. The other two regions, Vidarbha (VDB) and Western Maharashtra (WMH) have had 25% weight each in the total sample.

The 20 tehsils selected in the sample are listed in Table 8. Three tehsils each were selected from Nanded and Latur districts which have the highest area under rainy season sorghum. Jalgaon, Parbhani and Osmanabad, with medium concentration of rainy season sorghum area are represented by two tehsils each. The remaining eight districts with relatively less area under rainy season sorghum are represented in the sample by one tehsil each. The sample districts, tehsils and villages selected for the survey are shown in Figure 15.

Table 8. Tehsils selected for the sample in the study districts.

S.no	District	Tehsils	S.no	District	Tehsils
1	Akola	Patur	11	Nanded	Bhokar
2	Amravati	Daryapur	12	Nanded	Hadgaon
3	Beed	Kaij	13	Nanded	Mukhed
4	Dhule	Shirpur	14	Parbhani	Sonpeth
5	Hingoli	Aundha	15	Parbhani	Parbhani
6	Jalgaon	Muktainagar	16	Sangli	Khanapur
7	Jalgaon	Rawer	17	Satara	Karad
8	Latur	Devani	18	Osmanabad	Umarga
9	Latur	Latur	19	Osmanabad	Kalamb
10	Latur	Nilanga	20	Yavatmal	Pusad

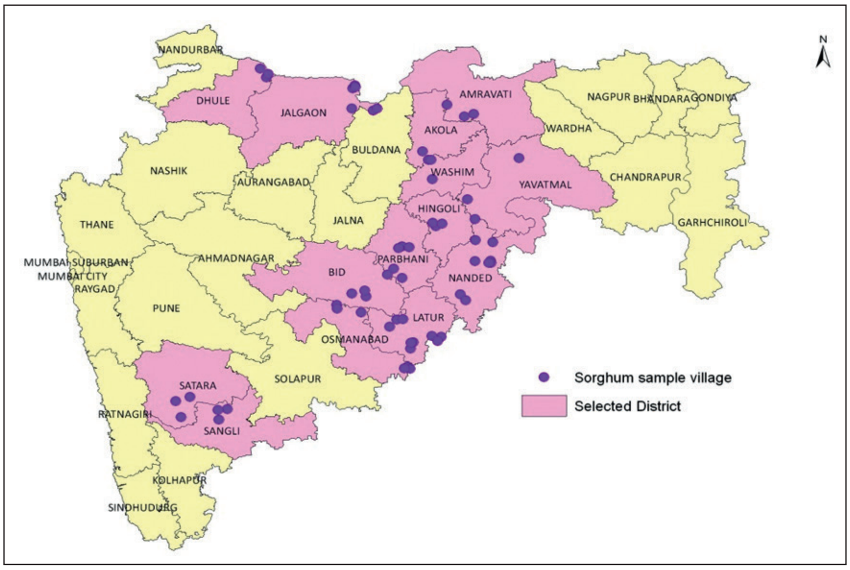


Figure 15. Selection of districts and villages for primary survey in Maharashtra.

4.2 Efficiency of the sample

Table 9 gives the distribution of rainy season sorghum area in Maharashtra in 2006-2011 (average). It clearly showed that the 91 tehsils, each having more than 5000 ha area under rainy season sorghum, together had a total area of 883,553 ha and it accounted for 77.2% of the total rainy season sorghum area in the country. By selecting 91 tehsils as population instead of 250 tehsils, we were able to capture more than three-fourths of the area by considering only about one third of the tehsils. The representative sample drawn from this population would, by and large, represent the whole rainy season sorghum area

Table 9. Distribution of rainy season sorghum area in districts of Maharashtra, 2006-2011.

District	No. of mandals with area > 0 ha of sorghum	Total area (ha)	No. of mandals with area > 1000 ha of sorghum	Total area (ha)	No. of mandals with area > 3000 ha of sorghum	Total area (ha)	No. of mandals with area > 5000 ha of sorghum	Total area (ha)
Ahmednagar	2	39	-	-	-	-	-	-
Akola	7	61296	7	61296	7	61296	7	61296
Amravati	14	62063	14	62063	11	53840	4	24891
Aurangabad	9	6709	2	5200	-	-	-	-
Beed	11	38522	5	36366	3	33305	3	33305
Buldhana	13	56256	13	56256	9	47926	4	26073
Chandrapur	9	3891	2	3545	-	-	-	-
Dhule	4	25274	4	25274	4	25274	3	21802
Hingoli	5	44899	5	44899	5	44899	5	44899
Jalgaon	15	117703	15	117703	15	117703	12	105704
Jalna	8	7173	4	6631	-	-	-	-
Kolhapur	11	8354	2	5053	1	3569	-	-
Latur	10	127656	10	127656	10	127656	10	127656
Nagpur	12	19519	6	18110	5	17042	-	-
Nanded	16	140184	16	140184	12	132632	10	124257
Nandurbar	6	27525	6	27525	5	25413	2	12045
Nashik	13	1607	-	-	-	-	-	-
Parbhani	9	69933	9	69933	8	67101	6	58701
Pune	11	5483	1	1356	-	-	-	-
Sangli	9	87264	9	87264	7	83367	6	79271
Satara	11	49332	7	49025	7	49025	4	36829
Solapur	7	223	-	-	-	-	-	-
Osmanabad	8	65455	7	65163	6	64130	5	60725
Wardha	8	7427	3	4378	-	-	-	-
Washim	6	34651	6	34651	6	34651	5	30137
Yavatmal	16	75927	16	75927	12	64765	5	35962
Grand Total	250	1144366	169	1125459	133	1053592	91	883553

in the state. This sampling strategy is quite efficient and cost-effective in capturing the diversity in the rainy season sorghum area in Maharashtra. In the total area under rainy season sorghum, Marathwada had a share of 44% (see appendix 1 and Table 10), followed by 28% each in the Western Maharashtra and Vidarbha regions. Sorghum area was distributed in a total of 250 tehsils from 26 districts.

But when only the tehsils with more than 5000 ha were considered, the number of tehsils dropped down to 91, which were drawn from 16 districts (Table 11). In this truncated population, 51% of the area belonged to Marathwada alone. Western Maharashtra had 29% share, while Vidarbha had a share of only 20%. By narrowing the population, the share of Marathwada increased at the expense of Vidarbha, but the share of Western Maharashtra remained about the same. To take care of these distortions, it was decided to give about 50% share in the sample to Marathwada and giving equal shares to Vidarbha and Western Maharashtra in the remainder of the sample.

Table 10. Region-wise distribution of sorghum crop (even > 0 ha).

Item	VDB	MTW	WMH	Pooled
No. of districts	8	8	10	26
No. of tehsil	85	76	89	250
Sorghum area (ha)	321030	500531	322804	1144366
% area to row total	28.05%	43.74%	28.21%	100.0%

Table 11. Region-wise distribution of sorghum crop *(> 5000 ha only).*

Item	VDB	MTW	WMH	Pooled
No. of districts	5	6	5	16
No. of tehsil	25	39	27	91
Sorghum area (ha)	178359	449543	255651	883553
% area to row total	20.18%	50.88%	28.94%	100.0%

4.3 Methodology for quantification of research benefits

Bantilan et al. (2013) emphasizes that the international research process is a complex activity and it is important to make sure an impact assessment study considers all aspects to avoid a wide range of potential aggregation and empirical errors. Figure 16 is the simplified schematic representation of the research process they used. It illustrates the sub-components of the complex interactions which ultimately lead to impacts and then changed welfare for the community. It highlights the importance of understanding the range of production environments (research domains) that are applicable to sorghum and especially the one(s) which generated the research focus on improved cultivars.

It notes the importance of understanding the strength of the adaptive research and adoption systems and their implications for quantifying final impacts. It also highlights the importance of understanding the effects of adoption of the new varieties on farmer's unit cost of production to understand the ultimate shift in supply in each region/country. It is this shift in supply that generates welfare changes for both sorghum producers and consumers and importantly many groups ultimately influenced by the initial sorghum market changes.

The welfare impacts consistent with the above framework can be estimated using formulas adapted from Bantilan et al. (2013; pages 34-36). This set of formulas includes all of the parameters from Figure 16.

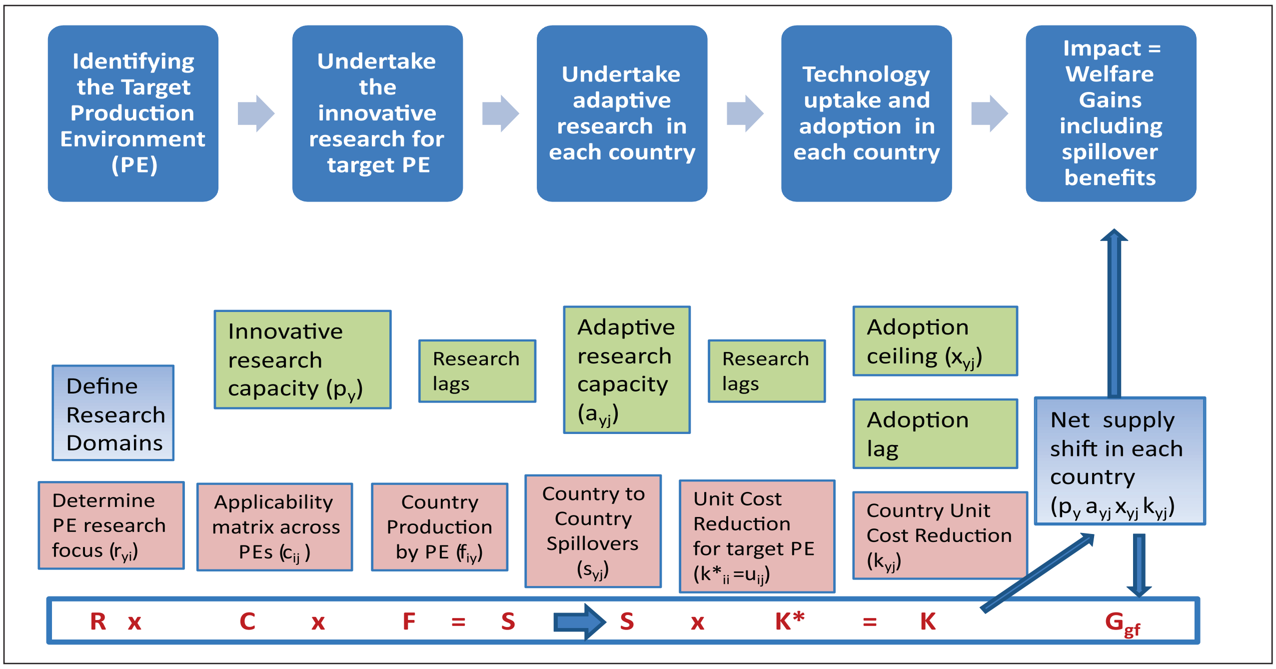


Figure 16. Research process and parameters required for welfare impact estimation.

Some are only important for *ex-ante* impact assessment analysis. They have been left in the formulae for this *ex-post* analysis and are indeed included in the spreadsheet model developed for the analysis. This is because it is important in the early stages of an impact assessment study to specifically consider all parameters and systematically give them a value after considering them carefully. In some case this may mean a value which means that parameter is redundant. For example in most *ex-post* studies the probability of innovative research success, p_{yt}, will be set at 1.[4]

The individual benefits for each farmer group, district, state or country 'f' from the research on sorghum improved cultivars 'g' (f = 1 ... n) are given as:

$$E[PV(G_{gf})] = \sum_{t=1}^{T} \sum_{f=1}^{n} \frac{p_{gt}\, a_{gft}\, x_{gft}\, k_{gft}}{(1+d)^{t}} Q_{sft}$$

$$+ \sum_{t=1}^{T} \frac{p_{gt}(Q_{dft} - Q_{sft}) \sum_{i=1}^{n} \beta_i\, a_{git}\, x_{git}\, k_{git}}{(1+d)^{t} \sum_{i=1}^{n}(\delta_i + b_i)}$$

$$+ \sum_{t=1}^{T} \frac{p_{gt}\, b_f \left(\sum_{i=1}^{n} \beta_i\, a_{git}\, x_{git}\, k_{git}\right)^{2}}{2(1+d)^{t}\left(\sum_{i=1}^{n}(\delta_i + b_i)\right)^{2}}$$

$$+ \sum_{t=1}^{T} \frac{p_{gt}\, \beta_f}{2(1+d)^{t}} \left[a_{gft}\, x_{gft}\, k_{gft} - \frac{\sum_{i=1}^{n} \beta_i\, a_{git}\, x_{git}\, k_{git}}{\sum_{i=1}^{n}(\delta_i + b_i)} \right]^{2} \quad ....(4.1)$$

Consumer benefits for each farmer group, district, state or country 'f' from the research on sorghum improved cultivars 'g' (f = 1 ... n) are given as:

$$E[PV(G_{cgf})] = \sum_{t=1}^{T} \frac{p_{gt}\, Q_{dft} \sum_{i=1}^{n} \beta_i\, a_{git}\, x_{git}\, k_{git}}{(1+d)^{t} \sum_{i=1}^{n}(\delta_i + b_i)}$$

$$+ \sum_{t=1}^{T} \frac{p_{gt}\, b_f \left(\sum_{i=1}^{n} \beta_i\, a_{git}\, x_{git}\, k_{git}\right)^{2}}{2(1+d)^{t}\left[\sum_{i=1}^{n}(\delta_i + b_i)\right]^{2}} \quad ....(4.2)$$

4. See more details at Bantilan et al. 2013

Producer benefits for each farmer group, district, state or country 'f' from the research on rainy season sorghum improved technology 'g' (f = 1 ... n) are given as:

$$E[PV(G_{pgf})] = \sum_{t=1}^{T} \frac{p_{gt} Q_{sft}}{(1+d)^t} [a_{gft} x_{gft} k_{gft} - \frac{\sum_{i=1}^{n} \beta_i a_{git} x_{git} k_{git}}{\sum_{i=1}^{n} (\delta_i + b_i)}]$$

$$+ \sum_{t=1}^{T} \frac{p_{gt} \beta_f}{2(1+d)^t} [a_{gft} x_{gft} k_{gft} - \frac{\sum_{i=1}^{n} \beta_i a_{git} x_{git} k_{git}}{\sum_{i=1}^{n} (\delta_i + b_i)}]^2 \quad \text{........ (4.3)}$$

Where:

p_{yt} is the probability of success of the innovative sorghum research undertaken by ICRISAT and its NARS partners 'y' in year 't' ($0 \leq p_{yt} \leq 1$). As was noted above this value was set to 1 in the analysis since the original research was successful;

a_{yft} is the probability of success of adaptive research undertaken in each district, state, country or region 'f' for the improved cultivars developed by ICRISAT and its partners 'y' in year 't' ($0 \leq a_{yft} \leq 1$). Again for most groups of farmers, districts, states and countries this parameter was set to 1. However, there are several of these where this adaptive research did not occur so the parameter was set to zero.

x_{yft} is the expected level of adoption of the new sorghum improved cultivars developed by ICRISAT and its partners 'y' by producers in each district, state, country or region 'f' (f = 1 … N) in year 't' ($0 \leq x_{yft} \leq 1$). This parameter can change each year and will. Underlying specifying this parameter is the complex set of understanding of the various research and adoption lags plus an assessment of when adoption reaches its ceiling level.

k_{yft} is the unit cost reduction (UCR) resulting from adoption of the sorghum improved cultivars developed by ICRISAT and its partners, 'y', in each district, state, country or region 'f' (f = 1 … N) in year 't'.

d is the social discount rate in real terms.

Q_{sft} is the quantity of sorghum produced in each district, state, country or region 'f' in time period 't' without research, that is, the counterfactual production level.

Q_{dit} is the quantity of the sorghum consumed in each district, state, country or region 'f' in time period 't' without research, that is, the counterfactual consumption level.

b_f and b_i are the slope parameters (dQ/dP) of the demand function in district, state, country or region 'f' or 'i'. Note that $b_i = e_{di} [Q_{dit}/P_{it}]$, where e_{di} is the elasticity of demand for the commodity in district, state, country or region 'i' evaluated at the original equilibrium prices and quantities, Q_{dit} and P_{dit}. Note that because negative signs are included in the demand specification the absolute value for these parameters are entered in the formulae.

$ß_f$ and $ß_i$ are the slope parameters (dQ/dP) of the supply function in district, state, country or region 'f' or 'i'. Also note, $ß_i = e_{si} [Q_{sit}/P_{it}]$ where e_{si} is the elasticity of supply.

N is the total number of districts producing and consuming sorghum in the Maharashtra state.

Figure16 includes a complex schematic for identification and modeling requirement of research domains, research applicability and spill overs between all producers and consumers of sorghum. This is achieved through adjusting the unit cost reduction (UCR), k, parameter. This was not formally used to calculate the UCR for each farmer grouping or district in the current study. However, the modelling process was used as a testing template for each UCR that was estimated for each unit.

A brief summary of the underlying relationship is:

K = K*S ....(4.4)

Where:

K is a matrix of monetary direct and indirect spillover unit cost reductions. K is an N x N matrix where N is the number of countries/regions in the world. Each component of K, that is, k_{yjt}, is then the unit cost reduction in country/region 'j' resulting from research undertaken in country/region 'y'.

K* is a diagonal matrix of potential cost reductions for each country. k^*_{yy} is the potential cost reduction in country 'y' where the (innovative) research is undertaken, with all $k^*_{yj} = 0$.

S is a matrix of research spillover indexes. In most cases it is expected that $0<s_{yj}<1$; although this is not a necessary condition of the framework.

S = R C F ....(4.5)

Where:

S is the same N x N spillover index matrix as in equation (4.5).

R is an N x m matrix of potential research focus parameters; 'm' is the number of production environments (research domains) relevant to production of the commodity and for a particular type of research problem being considered. Research can be focused on one production environment or a mix of them in different proportions by assigning an index r_{yi} $(0 \le r_{yi} \le 1)$ and $\sum_{i=1}^{m} r_{yi} = 1$ for country 'y'.

C is an m x m matrix of the research applicability's between production environments for each commodity, c_{ij}.

F is an m x N matrix of the shares of commodity production (production proportions) in each production environment for each country, f_{iy}. Again $\sum_{i=1}^{m} f_{iy} = 1$ for country 'y'.

Summary of data requirements

The minimum data requirements for the analysis using the *ex-post* framework outline in this section is embedded in the above discussion. It is worth briefly summarizing these with some brief comments here. In the application section these will be revised in detail and the important sources and adjustments to this data to support the analysis will be discussed in detail. For more details on parameters, please refer to appendix 4 in the report.

Parameter	***Assumptions/source of information****
Sorghum production and consumption data	Maharashtra Agricultural statistics, 2012-13
Farm gate price	Maharashtra Agricultural statistics, 2012-13
Research lag	Nine years of research lag were assumed from 1993 to 2001
Initial adoption lag	Three years lag were assumed from 2002 to 2004
Adoption lag	Nine years lag were assumed from 2005 to 2013
Ceiling level of adoption	100% (entire area will be covered)
Unit cost of reduction	Estimated based on primary household survey, 2012-13
Elasticity of supply	0.5 assumed based on literature review
Elasticity of demand	0.2 assumed based on literature review
Discount rate	5% assumed
Research costs	Costs were not estimated in the present study
Welfare benefits	Assumed for next 30 years (1993 to 2022)

* For more details refer to appendix 4.

The important sets of data are:

Final words of caution

The extensive body of applied welfare analysis literature assures us that the estimates of total welfare changes provided by application of this framework are very good approximations of what will occur. However, it cautions us about the final accuracy of the estimates for the distribution of these welfare changes. The economic framework is partial equilibrium so all the economic interactions are only the first round impacts on the Maharashtra sorghum markets. General equilibrium considerations tell us that the second and subsequent round interactions will dissipate these first round welfare distributions much more widely throughout local and world economies. The efficiencies and even inefficiencies (through the many government interventions) of all other markets in agriculture and the rest of the world economy will influence the final distribution of these welfare changes. These are very complex so the ultimate distributional impacts will often surprise many! However, the important point is that applied welfare economics theory tells us that as long as those applying the framework have a good understanding of this theory when making judgments about data selection and interpretation, then the total welfare changes are a very good approximation of what is achieved.

5. Household Survey Details

In order to further enhance the utility of the field survey, the survey team carried out a field level reconnaissance survey to zero in on the hybrids and cultivars of rainy season sorghum on which the survey has to be focused.

5.1 Reconnaissance survey

The economists along with consultant (a plant breeder) visited during June, 2013 all the 20 selected tehsils in the 13 districts which are important for rainy season sorghum in the state. They visited quite a few seed shops that marketed hybrid sorghum seed in these tehsils. By this reconnaissance survey, the survey team was able to assess the popularity of different sorghum hybrids, their approximate shares in the seed sales and their distinguishing characteristics that made them popular with the farmers. While some hybrids were preferred in some tehsils, the survey team could make a list of 10 to 20 popular hybrids/open pollinated varieties (OPVs) in the state on which the survey could be focused. The survey team also collected the names of villages where rainy season sorghum is mostly concentrated in the tehsil. To cross-check, the survey team also met the Taluka Agricultural Officers (TAOs) and discussed the hybrids that dominated the sorghum area in the rainy season. The sowing reports available with the agricultural officers were quite handy to verify and finalize the villages that should be included in the sample. Rainy season sorghum has been losing area rapidly throughout the state in the recent years. Soybean, cotton and maize are making in-roads in to several villages because of their higher profitability. The sowing reports were useful in identifying the villages that could be picked up for the survey.

5.2 Development of survey instruments

After the reconnaissance survey, the survey team has decided to classify the hybrids/varieties popular with the farmers into early varieties, medium duration varieties developed and first marketed before 2000 and those developed and first marketed after 2000. The early varieties are suitable for light soils and low rainfall areas. Some of the medium duration hybrids/varieties developed before 2000 are still favored by farmers in some areas although those developed and marketed after the year 2000 are popular in large areas. However, the share of early maturing varieties is relatively lower than medium duration cultivars. The survey team wanted to capture the yield gains and cost reductions as we move from the first (pre-2000 releases) group to the second (post-2000 releases). The survey team then designed the survey instruments to be used at the village level and at the household level. After receiving comments and suggestions from economists and bio-physical scientists, the team finalized the survey instruments.

5.3 Training program for the survey team

A training program was conducted for the survey team at Marathwada Agricultural University (MAU), Parbhani. The investigators were agricultural graduates and post-graduates with some exposure to surveys. The supervisor was experienced in conducting surveys, with more than three decades of work behind him. The economists and supervisor conducted the training for three days, with sorghum breeders chipping in as guest faculty. While visiting the shops during the reconnaissance survey, the survey team took photographs of seed packets of different hybrids and companies, which were shown to the investigators to give them an idea about the characteristics of the most popular hybrids (see appendix 3). Familiarity with the top hybrids was encouraged so that the investigators develop confidence while interacting with farmers as well as properly identify improved cultivars. Innovatively, an album was prepared with photographs of dominant improved cultivars identified during field reconnaissance survey. This has greatly assisted the field investigators to elicit the most accurate information about adoption from respondent farmers. This was possible because many sorghum farmers' could remember easily the attractive bag of seeds rather the name of the cultivar.

5.4 Pre-testing and conduct of survey

After the training, the next two days were spent on pre-testing the questionnaire. This was to ensure that the investigators understood the questions and would be able to put them across to the farmers with ease. If any questions were too ambiguous and did not bring forth proper responses from the farmers, they were marked and the survey team rephrased them. Questions were added, deleted and edited. This refinement process went on till the survey team and investigators were happy with the questions and the responses they elicited.

The survey group carried out the data collection work over 40 days during July-August, 2013 with a break of one week in between the first and second phases. Wherever possible, the support of the local agricultural staff was enlisted to clear the apprehensions and inhibitions of the respondents. Thus, the primary data were collected from a total of 360 sample farmers. One half of them were administered the input-output (costs-returns) module also. The supervisor backed up the investigators by correcting the filled-in questionnaires and by ironing out mistakes made in data collection. The village questionnaire was also administered during the survey in all the sample villages for gaining more confidence and to avoid the out layers in data.

6. Results and Discussions

The results of the study with sorghum farmers is summarized and discussed in this chapter. The details include household characteristics, landholdings, average cropping patterns and cropping systems, household assets, consumption expenditures, adoption of various sorghum improved cultivars, impacts of sorghum improved technology at farm-level, aggregated technology welfare benefits at the state level, costs and returns of different crop enterprises, competitiveness of rainy season sorghum vis-a-vis other crops, household networks and perceptions about household sustainability.

6.1 Characteristics of sample households

The characteristics of sorghum sample households across three regions of Maharashtra are analyzed and furnished in the below sub-headings:

6.1.1 Socio-economic features of sample

The sample farmers' have had an average experience of 21 years with farming and their experience with sorghum cultivation was only one year short of that (Table 12). All the households in the sample were headed by men. The average age of household heads was around 45 years with little variation across the three regions. The household head in all the three regions received about eight years of education.

The average size of household was slightly lower in Vidarbha than that in Marathwada, but the largest family size was noted in case of Western Maharashtra households. In all the three regions, males outnumbered females, highlighting the adverse sex ratio which has become a feature of many regions in India. In Vidarbha and Marathwada regions, about 60% of the family members contributed labor on their farms or in the labor market. This ratio was slightly lower at 57% in case of Western Maharashtra households, denoting a slightly higher dependency ratio. Participation in the labor market was the lowest in Marathwada with only 36% of the workers seeking work outside their farm. It was higher in case of Vidarbha, where 43% of the workers in a typical family sought work outside their farm. But, it was in Western Maharashtra, where nearly 46% of the workers in the family looked for wage labor opportunities.

6.1.2 Occupational structure of households

About 90% of the households in Vidarbha and Marathwada regions had agriculture as their main occupation, highlighting the preponderance of farming in the lives of the people (Table 13). But the occupational pattern is more diversified in Western Maharashtra region, with only 69% of the households having agriculture as their main occupation. Livestock rearing was the main occupation for 8% of the households in this region. In Vidarbha and Western Maharashtra, those drawing main income from salaried jobs were relatively less. This proportion was slightly higher in Marathwada. Non-farm labor opportunities were also less in Vidarbha than in Marathwada region. But it was in Western Maharashtra, where both non-farm labor opportunities and other occupations provided main source of income to a significant proportion of the sample. Other occupations were more important in Vidarbha than in Marathwada.

Agriculture was the supplementary source of income for the households that depended on non-agricultural sources as their main source of income. Livestock provided supplementary income to a significant proportion of the sample in all the regions. So also was the non-farm work important in providing income to farmers in all the regions. About 15% of the sample did not have any source of secondary income. Income from rents earned from property was quite insignificant as a source of secondary income in all the regions. Other miscellaneous sources provided some income support to some households in all the regions.

Table 12. Socio-economic features of sample households.

Description	Unit/ gender	VDB (N=90)	MTW (N=180)	WMH (N=90)	Pooled (N=360)
Years in farming	Years	20.98	20.45	21.62	20.87
Years in sorghum farming	Years	19.68	18.27	20.72	19.23
Household head	no. male	90	180	90	360
	no. female	0	0	0	0
Average age of household head	Years	44.60	45.07	46.81	45.39
Education (years completed)	Years	8.14	7.88	7.93	7.96
Average size of family*	No.	5.02	5.42	5.66	5.38
Males in family*	No.	2.93	3.10	3.08	3.05
Females in family*	No.	2.09	2.32	2.58	2.33
Members worked as a family labor (no.)	Male	1.69	1.84	1.76	1.78
	Female	1.29	1.46	1.49	1.42
	Total	2.98	3.30	3.25	3.20
Members participating in labor market (no.)	Male	0.73	0.74	0.78	0.75
	Female	0.56	0.47	0.70	0.55
	Total	1.29	1.21	1.48	1.30

* includes children

Table 13. Details of occupational structure of sample farmers (no.).					
Item	Description	VDB (N=90)	MTW (N=180)	WMH (N=90)	Pooled (N=360)
Main Occupation	1. Agriculture	81	163	62	306
	2. Livestock	0	0	7	7
	3. Salaried employee	2	6	2	10
	4. Non-farm labor	1	8	9	18
	5. Others	6	3	10	19
Secondary occupation	1.Agriculture	8	14	25	47
	2. Livestock	38	86	21	145
	3. Salaried employee	4	6	3	13
	4. Income from rentals	0	1	2	3
	5. Non-farm labor	25	29	23	77
	6. Others	4	20	7	31
	7. None	11	24	9	44
Caste category	1.OC	25	105	41	171
	2.OBC	16	29	23	68
	3.SBC	1	0	0	1
	4.SC	6	7	6	19
	5.ST	6	16	13	35
	6.Nomatic tribes	36	23	7	66

Other or forward castes formed about 58% of the sample in Marathwada. This proportion was about 46% in the Western Maharashtra sample. They constituted only 28% of the sample in Vidarbha. Nomadic tribes formed the highest proportion of the sample in Vidarbha, while their share was lower in Marathwada. They had the least share in Western Maharashtra sample. Other Backward Castes and Scheduled Tribes had significant shares in the sample of Western Maharashtra. Relatively, their shares were lower in other regions. Scheduled Castes and Socially Backward Castes did not have significant presence in the farmers' sample in any of the regions.

6.1.3 Landholding particulars

The details of landholdings of the sample farms in the three regions of Maharashtra are furnished in Table 14. The average size of ownership holding was the biggest in Marathwada and the smallest in Western Maharashtra. It was 2.95 ha in Vidarbha, but only 13% of it was irrigated. In Marathwada, about 26% of the holding (3.46 ha) was irrigated. Although the holding in Western Maharashtra was the smallest at 2.82 ha, about 34% of it was irrigated. Leased-in land was insignificant in all the three zones. Same was the case with the leased out land, except that it was noted in small measure in Western Maharashtra. The operational holding was the same as the ownership holding in Marathwada; it was marginally bigger in Vidarbha; and it was a little smaller in Western Maharashtra.

6.1.4 Cropping systems and cropping pattern

Since sorghum is a rainfed crop, nearly two-thirds of the land allocated to rainy season sorghum is likely to be left fallow in the postrainy season (Table 15). About 14.3% of the land with good moisture retention capacity could be cropped with chickpea in the postrainy season. About 12.7% sorghum area has irrigation facility and wheat is grown in the postrainy season in such lands. Although it is not desirable to grow sorghum after sorghum, some 6.3% of the rainy season sorghum area is devoted to sorghum again in the postrainy season. Very small areas where rainy season sorghum is grown are allocated to crops like maize, onion, sunflower and safflower in the postrainy season.

Table 14. Average landholding size of sample household (ha per HH).

Item	Land type	VDB (N=90)	MTW (N=180)	WMH (N=90)	Pooled (N=360)
Total own landholding	Irrigated	0.39	0.89	0.97	0.78
	Rainfed	2.57	2.58	1.85	2.39
	Total	2.95	3.46	2.82	3.18
Leased-in land	Irrigated	0.00	0.00	0.00	0.00
	Rainfed	0.01	0.04	0.00	0.03
	Total	0.01	0.04	0.00	0.03
Leased out/permanent fallow	Irrigated	0.00	0.00	0.00	0.00
	Rainfed	0.00	0.04	0.09	0.04
	Total	0.00	0.04	0.09	0.04
Operated landholding	Irrigated	0.39	0.89	0.97	0.78
	Rainfed	2.58	2.58	1.76	2.38
	Total	2.97	3.46	2.73	3.16

Table 15. Major sorghum cropping systems in Maharashtra (ha).

Cropping system	Proportion of total rainy sorghum (%)
Sorghum (rainy)- Fallow	64.6
Sorghum (rainy)+ Pigeonpea - Fallow	0.10
Sorghum (rainy)- Safflower	0.70
Sorghum (rainy)- Chickpea	14.3
Sorghum (rainy)-Wheat	12.7
Sorghum (rainy)- Sorghum (postrainy)	6.30
Sorghum (rainy) – Onion	0.40
Sorghum (rainy) – Maize	0.40
Sorghum (rainy) – Sunflower	0.30

6.1.5 Household assets

The average value of assets of a sample household was the highest in Marathwada region and it was the lowest Vidarbha, with Western Maharashtra lying in between (Table 16). The total value of assets of a sample household in Marathwada was about 19% higher than that of a Western Maharashtra household and was about 39% higher than that of a Vidarbha household. These differences in asset values were on account of differences between the land values in the three regions. The value of non-land assets was about the same in Marathwada and Western Maharashtra and it was marginally lower in Vidarbha. The value of irrigated land was the highest in Marathwada, followed by Vidarbha. The value of dryland was the highest in Western Maharashtra, followed by the same in Marathwada. The land value of the pooled sample alone accounted for 89% of the total value of assets. The value of farm buildings had a share of 6% in the assets. The value of livestock and that of consumer durables had 2% share each. Farm equipment filled the gap of the remaining 1%.

6.1.6 Household incomes

Just as the average value of assets was the highest in Marathwada, so also was the average net income per household (Table 17). A sample household in Marathwada had 17% higher income than that in Western Maharashtra and 32% higher income relative to its counterpart in Vidarbha. And these differences were

Table 16. Average value of household assets ('000 USD per HH).

Item	VDB (N=90)	MTW (N=180)	WMH (N=90)	Pooled (N=360)
Total land value	69.42	98.51	81.80	87.06
1.Irrigated	56.77	65.04	33.74	55.15
2. Dryland	12.65	33.13	47.29	31.55
3. Fallow land	0.00	0.34	0.77	0.36
Total livestock value	1.89	1.80	2.17	1.91
Draft	0.79	0.85	0.65	0.79
Buffaloes	0.43	0.43	0.79	0.52
Others	0.67	0.51	0.73	0.61
Total farm equipment	0.56	0.99	1.57	1.03
Total farm buildings	5.28	6.40	5.09	5.79
Total consumer durables	1.78	2.34	2.06	2.13
Total assets value	78.94	110.04	92.69	97.93

Note: 1 USD = INR 55

Table 17. Average household net incomes ('000 USD/HH/annum).

Source of income	VDB (N=90)	MTW (N=180)	WMH (N=90)	Pooled (N=360)
Agriculture	1.68	2.65	1.78	2.19
Farm labor	0.20	0.21	0.26	0.22
Non-farm Labor	0.02	0.04	0.02	0.03
Livestock	0.26	0.20	0.39	0.26
Caste occupation	0.02	0.00	0.04	0.02
Business	0.26	0.22	0.28	0.24
Govt. development programs	0.07	0.07	0.08	0.07
Salaried	0.27	0.29	0.28	0.29
Rentals	0.09	0.11	0.14	0.12
Out-migration	0.00	0.00	0.01	0.00
Others	0.00	0.00	0.00	0.00
Grand total	2.87	3.80	3.28	3.44

Note: 1 USD = INR 55

on account of the variations in income from agriculture. A Marathwada household received 49% more income from agriculture than a Western Maharashtra household and 58% more income from agriculture than a Vidarbha household. After agricultural income, farm labor, livestock, business and salaried jobs provided supplementary income in, almost, equal measure. Rental income, non-farm labor, caste occupations and government development programs provided trickles of income to the households. For the pooled sample, about 64% of the income came from agriculture, 8% each from salaried jobs and livestock, 7% from business and 6% from farm labor. Rental income provided about 3% of the income and governmental programs contributed 2% of the income. The remaining 2% came from non-farm labor and caste occupations. Agriculture provided about 70% of the household income in Marathwada, while it provided less than 55% of the incomes in Vidarbha and Western Maharashtra. Hence, the dependence of these two regions on non-agricultural sources was higher than in the case of Marathwada.

6.1.7 Household consumption expenditure

Since the asset base and income levels were higher for Marathwada, the consumption expenditure was also higher in that region (Table 18). The annual average consumption expenditure in Marathwada was 11% higher than that in Western Maharashtra and 23% higher than in Vidarbha. In all the three regions, non-food expenditure was higher than the food expenditure. In the pooled sample, a sample household spent 44% of total expenditure on food and the remaining 56% on non-food items. Of the food expenditure, 29% was spent on cereals and about 19% on pulses. The expenditure on milk and milk products was equal to what was spent on cereals (29%) and the remaining 22% was spent on other food items. Among cereals, expenditure on wheat was the highest, closely followed by sorghum. Expenditure on rice and other cereals was quite less. Expenditures on education, health and clothing were the major components of non-food expenditure. Ceremonies, entertainment and travel are the other important components of non-food expenditure.

An average household in the pooled sample spent only 39% of the income earned on consumption items. Perhaps, the remaining amount was used towards clearing old debts, saving for future needs or for productive investments. The per capita expenditure worked out to about USD 0.7 per day, which meant that the consumption standards of the sample households were quite poor relative to the definition of poverty used by the World Bank.

6.1.8 Importance of rainy season sorghum in sample households

Among the rainy season cropping pattern, sorghum still figures prominently in all the three regions of Maharashtra (Table 19). Soybean has emerged as the most important rainy season crop in Vidarbha region, followed by sorghum and cotton. Green gram has some significant area in this region. But all other crops occupied only nominal areas in the cropping pattern. In Marathwada region also, soybean has a little

Table 18. Average household consumption expenditures ('000 USD/HH/annum).

Commodity	VDB (N=90)	MTW (N=180)	WMH (N=90)	Pooled (N=360)
Rice	0.03	0.03	0.04	0.03
Wheat	0.06	0.08	0.08	0.07
Sorghum	0.05	0.06	0.07	0.06
Other cereals	0.00	0.01	0.01	0.01
Pigeonpea	0.06	0.07	0.07	0.07
Chickpea	0.02	0.02	0.02	0.02
Other pulses	0.02	0.02	0.02	0.02
Milk	0.10	0.15	0.12	0.13
Other milk products	0.03	0.04	0.05	0.04
Other food expenditure	0.13	0.13	0.13	0.13
Non-food expenditure	0.15	0.19	0.22	0.19
Non-vegetarian	0.004	0.004	0.004	0.004
Health	0.14	0.17	0.13	0.15
Clothing	0.11	0.13	0.11	0.12
Education	0.15	0.21	0.16	0.18
Ceremonies	0.04	0.05	0.04	0.05
Entertainment/travel	0.04	0.05	0.06	0.05
Others	0.00	0.01	0.00	0.01
Grand total	1.13	1.42	1.34	1.33

Note: 1 USD = INR 55

edge over cotton, but sorghum is pushed to a distant third position. Other crops like sugarcane, green gram, pigeonpea had small areas under them. In Western Maharashtra alone, rainy season sorghum had a small edge over cotton and soybean, maize, banana, green gram covered small areas. In the pooled sample, cotton, soybean and sorghum were the important crops in the rainy season, followed by green gram, sugarcane, maize and banana. Pigeonpea has lost its sheen as a sole crop, although it still figures in inter-cropping systems.

In the postrainy season, chickpea occupied the highest area (0.69 ha) in Vidarbha region. It was distantly followed by sorghum (postrainy) with 0.08 ha (Table 20). Wheat occupied still lower area with 0.09 ha. Other crops together covered 0.008 ha. Considerable area was left fallow. In Marathwada, chickpea was the most important crop with 0.85 ha, followed by sorghum with 0.24 ha and wheat with 0.127 ha. Around 2.22 ha were left fallow in the region. Wheat occupied the highest area of 0.31 ha in Western Maharashtra. Postrainy sorghum came next with an area of 0.189 ha, followed by chickpea with 0.12 ha. Maize, maize fodder and onion have also occupied marginal areas in the region. But, major chunk of the cropped area in the region is left fallow. Overall, chickpea, sorghum (postrainy) and wheat were the dominant crops in the study locations of Maharashtra.

Table 19. Average rainy season cropping pattern of sample households (ha per HH).

Crops	VDB (N=90)	MTW (N=180)	WMH (N=90)	Pooled (N=360)
Cotton	0.535	1.020	0.845	0.856
Soybean	0.924	1.045	0.161	0.794
Sorghum (rainy)	0.724	0.665	0.929	0.739
Soybean + Pigeonpea	0.222	0.377	0.058	0.259
Green gram	0.236	0.066	0.081	0.112
Cotton+ pigeonpea	0.058	0.080	0.072	0.073
Sugarcane	0.026	0.089	0.013	0.055
Maize	0.000	0.009	0.182	0.050
Banana	0.000	0.000	0.188	0.047
Pigeonpea (PP)	0.042	0.037	0.00	0.029
Others	0.123	0.060	0.113	0.082
Fallow	0.080	0.012	0.088	0.064
Total	2.970	3.460	2.730	3.160

Table 20. Average postrainy season cropping pattern of sample farmers (ha per HH).

Crops	VDB (N=90)	MTW (N=180)	WMH (N=90)	Pooled (N=360)
Chickpea	0.690	0.850	0.120	0.630
Maize	0.000	0.000	0.038	0.009
Maize fodder	0.000	0.000	0.013	0.003
Onion	0.000	0.000	0.013	0.003
Safflower	0.004	0.019	0.000	0.010
Sorghum (postrainy)	0.080	0.240	0.189	0.189
Sunflower	0.004	0.004	0.000	0.003
Wheat	0.090	0.127	0.310	0.164
Fallow	2.100	2.220	2.050	2.149
Total	2.970	3.460	2.730	3.160

Sorghum has lost its pre-eminence in the cropping patterns of all the three regions in the recent decades. In Vidarbha region, rainy season sorghum accounted for about one-fourth of the cropped area in the rainy season (Table 21). But in the total cropped area, rainy season sorghum had around 20% share. In Marathwada region, rainy season sorghum had a share of one-fifth in the cropped area during the rainy season. In the total cropped area, it still held a 15% share. In Western Maharashtra, rainy season sorghum had a more prominent place with one-third of the cropped area under it. But it formed about 27% of the total cropped area. Thus, rainy season had relatively bigger share in the cropped area in Western Maharashtra, followed by Vidarbha and Marathwada regions. Overall, the sample farmers, on an average, allocated one-fourth of their rainy season cropped area to sorghum.

The pattern of utilization of grain and fodder was more or less similar in the three regions. Very little of the produce is saved for seed because of farmers' dependence on hybrids, whose seed has to be purchased from the market year after year (Table 22). About 14 % of the grain produced is used as kind payments to pay labor and for gifts to friends and relatives. About 19% of the grain production is used for consumption. Nearly 63% of the sorghum grain produced is sold in the market. The remaining 4% is kept in store for precautionary purposes. With respect to fodder, 88% of production is used for feeding the animals. About 8% of the total fodder produced is sold in the market. The remaining quantity is either passed on to needy friends or relatives or kept in store. This clearly reflects that rainy season sorghum is being grown primarily as a cash crop for grain, and as a feed crop for livestock.

6.2 Technology adoption and impacts

The pattern of adoption of rainy season improved cultivars over time, their impact on crop productivity and the extent of welfare accrued due to improved technology etc are summarized in the following sub-sections:

Table 21. Importance of rainy season sorghum in sample households (ha).

Item	VDB (N= 90)	MTW (N=180)	WMH (N=90)	Pooled (N=360)
Total cropped area	343.7	848.08	309.26	1501.97
Cropped area in the rainy season	265.4	624.88	248.06	1138.37
Cropped area in the postrainy season	78.3	223.2	61.2	363.6
Sorghum (rainy) cropped area	65.59	124.8	83.60	273.99
% Sorghum in rainy season area	24.7	20.0	33.7	24.1
% Sorghum area in total cropped area	19.1	14.7	27.0	18.2

Table 22. Utilization of sorghum by the sample households, 2012-13.

	Vidarbha		Marathwada		Western Maharashtra		Overall	
Item	Grain	Fodder	Grain	Fodder	Grain	Fodder	Grain	Fodder
Total production	1312.67	2923	1258.61	2975	1884.33	3830	1428.56	3176
Saved as seed	0.00	0.00	1.11	1.0	0.00	0.00	0.56	1.0
Gift/kind payments	162.33	47	187.06	91	258.33	72	198.69	75
Used as feed/food	259.89	2706	200.28	2545	398.44	3391	264.72	2797
Sold in market	817.56	140	824.06	293	1165.33	312	907.75	260
In store	72.89	31	46.11	45	62.22	54	56.83	44

Unit=kg per HH

6.2.1 Pattern of first adoption and sources of seed

With respect to sample farmers' first adoption information, CSH 9 was adopted by 312 farmers at some time or the other, making it the most lasting hybrid in Maharashtra (Table 23 and Figure 17). Mahyco 51 was adopted by 243 farmers at some time or the other, making it the next popular variety after CSH 9. It is distantly followed by MLSH 296 (154 farmers) and JKSH 22 (127 farmers). ProAgro 8340 (89 farmers) and CSH 14 (65 farmers) were the least popular in the total period. Perhaps, they are coming up in the recent years and are yet to peak in adoption.

The first adoption patterns of important sorghum hybrids were depicted by graphs in Figure 17 for overall Maharashtra sample; in Figure 18 for Vidarbha sample; in Figure 19 for Marathwada sample; and in Figure 20 for the Western Maharashtra sample. By and large, CSH 9 (dark red line) and Mahyco 51 (light green line) followed similar patterns, while MLSH 296 (violet line), ProAgro 8340 (blue line) and JKSH 22 (orange line) followed similar trends in adoption. Other hybrids such as CSH 5, CSH 14, PAC 537 and PAC 501 were adopted by fewer farmers and are represented by different colors in different graphs.

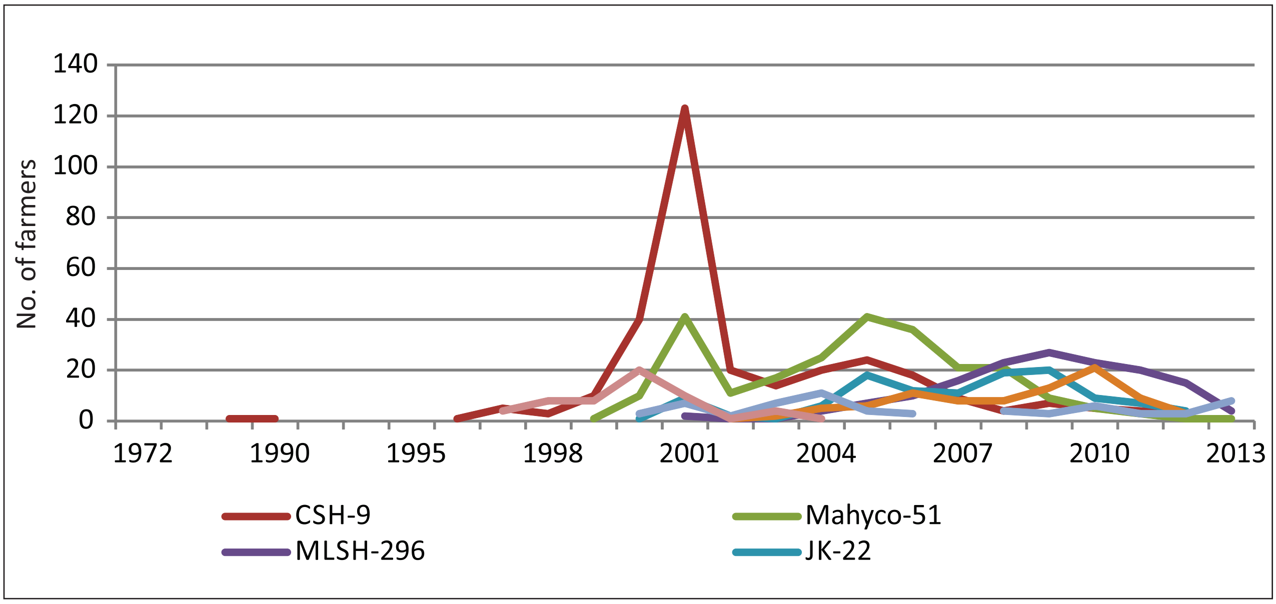


Figure 17. First adoption pattern of major sorghum improved cultivars in the sample (no.).

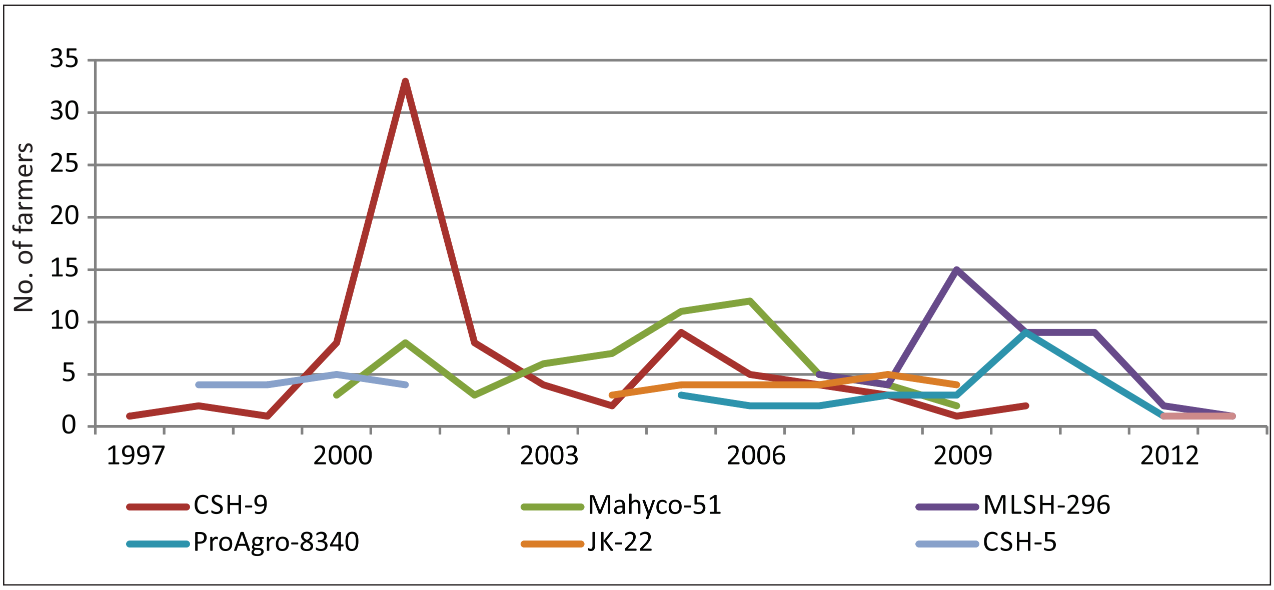


Figure 18. First adoption pattern of major sorghum improved cultivars in Vidarbha region (no.).

Table 23. Summary data on first adoption of sorghum improved cultivars in the sample (no.).							
Year of adoption	CSH 14	CSH 9	JKSH 22	Mahyco 51	MLSH 296	ProAgro 8340	Grand Total
1985		1					1
1990		1					1
1993	1						1
1995			1				1
1996		1					1
1997		5					5
1998		3					3
1999		10		1			11
2000	3	40	1	10		2	56
2001	7	123	9	41	2		182
2002	2	20	2	11	1	1	37
2003	7	14	1	17	2	2	43
2004	11	20	6	25	4	5	71
2005	4	24	18	41	7	6	100
2006	3	18	13	36	10	11	91
2007		9	12	21	16	8	66
2008	4	4	20	21	23	8	80
2009	3	7	22	9	27	13	81
2010	6	5	10	5	23	21	70
2011	3	4	8	3	20	9	47
2012	3	3	4	1	15	3	29
2013	8	-	-	1	4	-	13
Total	65	312	127	243	154	89	990

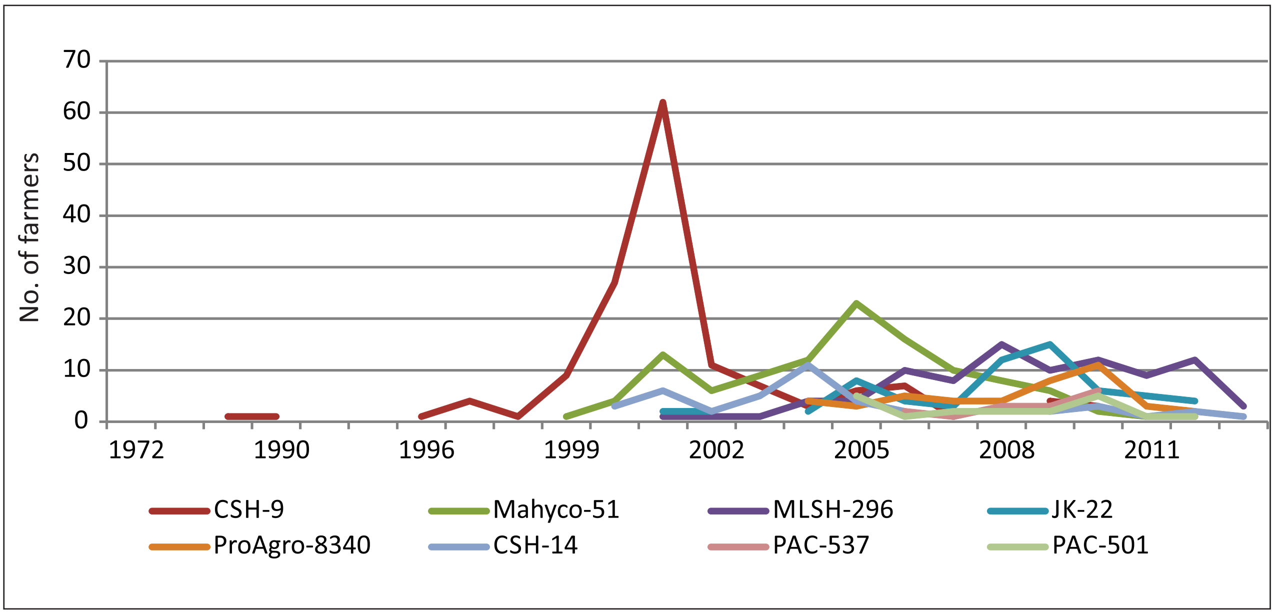


Figure 19. First adoption pattern of major sorghum improved cultivars in Marathwada region (no.).

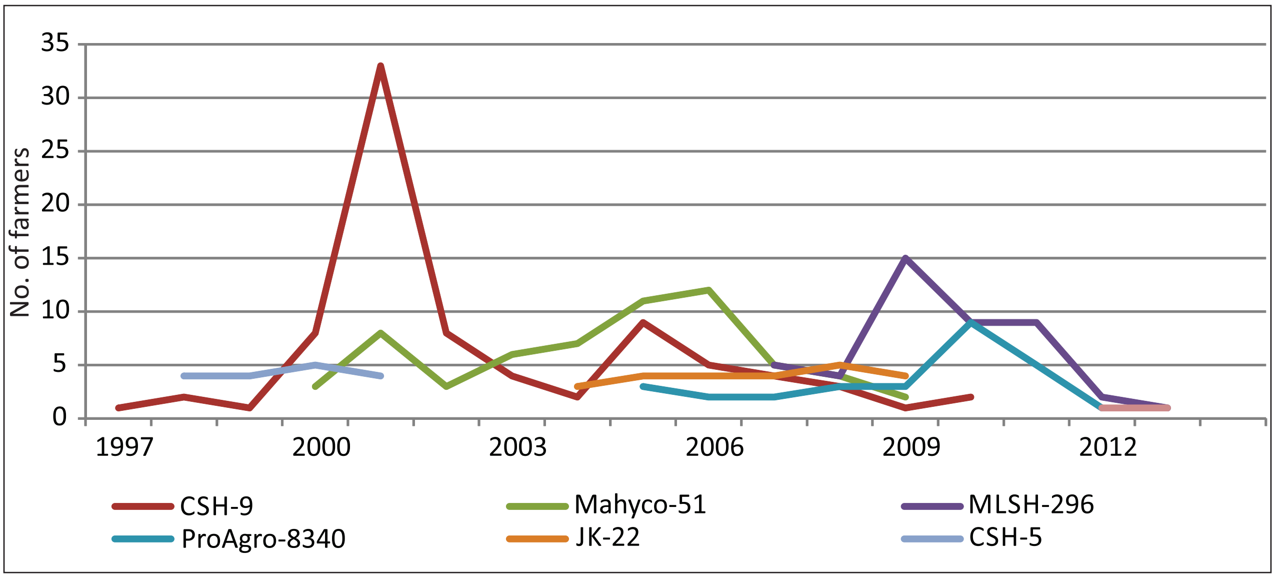


Figure 20. First adoption pattern of major sorghum improved cultivars in Western MH region (no.).

CSH 9 was first adopted in 12 ha in Vidarbha during the period 1996 to 2000 (Table 24). But the bulk of the area (56 ha) first came under it in the period 2001-2005. It was adopted in another 15 ha in the period, 2006-2010. Thus, in all, it was grown in 83 ha by the sample farmers at some time or other. Mahyco 51 also has a similar pattern of first adoption as CSH 9 in Vidarbha region. In all, it was grown in 62 ha by the sample farmers over the period covered in the enquiry. It started with 3 ha during 1996-2000 and then gained momentum from 2001 to 2005, when it covered 35 ha by the new adopters. It was further adopted in 23 ha during 2006-10 and another ha after 2010. CSH 9 and Mahyco 51 exhibited similar patterns of first adoption in Vidarbha region, although CSH 9 was adopted in more area than Mahyco 51. The other three varieties, MLSH 296, ProAgro 8340 and JKSH 22 followed comparable pattern of adoption. They covered small areas in Vidarbha during 2001-05; the bulk of the adoption took place during 2006-2010; and some areas after 2010. In all, 46 ha were put under MLSH 296; 28 ha were under ProAgro 8340; and 26 ha were brought under JKSH 22 in the total study period.

Similar patterns of first adoption were noted in Marathwada and Western Maharashtra regions for these five varieties. CSH 9 was adopted in Marathwada in 2 ha even before 1995. It was adopted in 42 ha between 1996 and 2000 and the adoption area doubled between 2001 and 2005. Even during 2006-2010, 15 ha were brought under it and 1 ha was brought after 2010. In all, 149 ha area was brought under it by the sample farmers in some period or the other, which testifies to its popularity.

Mahyco 51 was adopted in 5 ha between 1996 and 2000; 63 ha was brought under it during the period 2001-2006; and another 42 ha was brought under it between 2006 and 2010; and two ha area was brought under it even after 2010. Thus, Mahyco 51 stands only second after CSH 9 in terms of popularity, with a total of 112 ha brought under it in some period or the other.

The adoption of MLSH 296 started from 2001 to 2005 but gained momentum between 2006 and 2010 and continued gaining acceptance even after 2010. ProAgro 8340 was tried in small areas during 1996 to 2000; but it gained acceptance from 2001 to 2006 and became popular between 2006 and 2010. Even after 2010, it was adopted in 5 ha. JKSH 22 was tried in one ha even before 1995, it was allocated considerable area between 2001 and 2005. But it really became popular in the period, 2006-2010. It was adopted in 9 ha even after 2010. Among the three new varieties, MLSH 296 was adopted in about 90 ha area; ProAgro 8340 was tried in 47 ha; and JKSH 22 was used in 64 ha.

Table 24. Pattern of first adoption of improved cultivars across three regions (in ha).

	Vidarbha region					Marathwada region					Western Maharashtra region				
Year	CSH 9	Mahyco 51	MLSH 296	ProAgro 8340	JKSH 22	CSH 9	Mahyco 51	MLSH 296	ProAgro 8340	JKSH 22	CSH 9	Mahyco 51	MLSH 296	ProAgro 8340	JKSH 22
Before 1995	-	-	-	-	-	2	-	-	-	1	-	-	-	-	-
1996-2000	12	3	-	-	-	42	5	-	2		5	3	-	-	1
2001-2005	56	35	1	3	8	89	63	11	8	14	56	37	3	3	14
2006-2010	15	23	33	19	17	15	42	55	32	40	13	27	11	10	14
After 2010	-	1	12	6	1	1	2	24	5	9	6	2	3	1	1
Total	83	62	46	28	26	149	112	90	47	64	80	69	17	14	30

Even in Western Maharashtra, CSH 9 was adopted in 80 ha. Its adoption started in a trickle between 1996 and 2000, but soon peaked between 2001 and 2005. It continued to attract new areas in the period, 2006-2010 and even after 2010. Mahyco 51 shared the same time line, with three farmers trying it in 3 ha between 1996 and 2000, but the bulk of adoption (37 ha) took place between 2001 and 2005. It spread to 27 ha between 2006 and 2010. It was tried in 2 ha even after 2010. In all, it was adopted in 69 ha by the sample farmers of Western Maharashtra at some point of time or the other. Among the three new varieties, JKSH 22 was the most popular with area coverage of 30 ha. It was tried only in 1 ha between 1996 and 2000, but it became popular in the next two five-year periods, 2001-2005 and 2006-2010, covering 14 ha in each of the periods. Even after 2010, it was adopted 1 ha. MLSH 296 and ProAgro 8340 followed similar trends. They were tried in small areas between 2001 and 2005; but gained steam from 2006 to 2010 and they continued to attract new areas even after 2010.

Even when all the regions were taken together, CSH 9 was adopted in the highest area of 312 ha. It was followed by Mahyco 51, which was adopted in 243 ha. Among the relatively new varieties, MLSH 296 was used in 153 ha. JKSH 22 was adopted in 120 ha, while ProAgro 8340 was grown in 89 ha.

Table 25 furnished information on the percentages of farmers hearing about new hybrid varieties of sorghum from different sources in the years of their first adoption. In all the three regions, private seed shops gave out most information about new hybrid varieties to a large percentage of the farmers. Government extension officers and agencies provided this information to only about one-sixth of farmers. Next in importance were the fellow farmers who passed on the relevant information. Mass media like radio and newspapers could provide information to hardly 3-4% of the farmers. Other sources of knowledge such as research centers, farmers' associations, demonstrations and on-farm trials informed only insignificant fractions of the sample.

In the year of first adoption, private seed shops supplied hybrid seeds to more than 90% of the farmers in all the three regions. All other sources such as research centers, extension agencies, farmers' clubs etc, could supply the seeds of new varieties to less than 5% of the sample farmers. Since most of the improved varieties were from the private seed companies, it is but natural that seed dealers would access the seeds and sell them to the farmers.

Reasons for cultivation of sorghum in the rainy season

Rainy season sorghum is grown by farmers for grain and fodder. It is also grown because the soil and climate are suitable and it is necessary to rotate crops between cotton, soybean, green gram and sorghum to keep up soil fertility. The sample farmers were asked to give weights to these four different purposes for growing sorghum in the rainy season. In all the three regions, more than 50% of the farmers said they were mainly grew sorghum in the rainy season for purposes of fodder (Table 26). About 34 to 41%

Table 25. Major sources of information and seed for the first adoption (%).

Sources of Information				Sources of seeds			
Source	VDB	MTW	WMH	Source	VDB	MTW	WMH
Private shop	68.4	61.1	62.2	Research PVS/Univ	1.0	1.4	0.0
Govt. extension	13.1	18.2	15.9	Extension demo plots	0.3	0.0	0.3
Fellow farmers	12.0	17.0	13.8	Farmers' club/villagers	0.3	1.2	0.3
Newspaper/radio	4.2	3.4	3.1	Local seed producers	0.0	0.3	0.0
Research center/univ.	0.8	0.0	2.6	Local trader	95.6	91.1	96.3
Farmer association	0.8	0.3	2.1	Farmer-to-farmer seed exchange	0.3	0.2	0.0
On-farm trials/demos	0.8	0.0	0.2	Free from NGOs	0.0	0.2	0.0
NGO	0.0	0.0	0.1	Free from govt. agency	2.5	5.6	3.1
				Own seed	0.0	0.2	0.0

Table 26. Reasons for growing rainy season sorghum (mean weight out of 100).				
Reasons	VDB (N=90)	MTW (N=180)	WMH (N=90)	Pooled (N=360)
Crop rotation	1.78	2.47	0.35	1.70
For fodder	55.33	58.61	51.70	56.06
For grain	38.61	34.19	41.33	37.09
Suitable to soil and climate	4.28	4.72	6.62	5.15
Grand total	100.00	100.00	100.00	100.00

of farmers indicated that grain was their primary purpose. About 5% in all three regions said they found that soil and climate were suited to the crop. A negligible proportion of the sample attributed growing sorghum for rotation. These responses do not mean that farmers get more income from fodder than from the grain. However, there is a larger uncertainty associated with the quantity and quality of grain obtained from sorghum due to weather aberrations. So, the farmers treat fodder as a certain output and grain as an uncertain output and, hence, attach greater value to fodder. The uncertain grain production and low the price it receives render sorghum an unviable crop enterprise and this is the main reason for decline of area under it.

With the increasing livestock rearing opportunities and higher demand for milk, majority of sample farmers were engaged in livestock enterprise and indicated it as their major secondary sources of household income. This synergy of crop-livestock interaction might be one of the reason that the sample farmers are still persistent with rainy season cultivation despite of its being less profitable than other rainy season crops.

6.2.2 Adoption of rainy season sorghum improved cultivars

During the last three seasons, 2010-11 to 2012-13, new varieties have come to occupy the bulk of areas under sorghum (Table 27) in the Vidarbha region. In all the three years, MLSH 296 (Dev Gen) topped the list of 11 hybrids in terms of area coverage, nearly accounting for 24 ha of the total area of 70 ha under rainy season sorghum. It alone had a market share of 34%. ProAgro 8340 occupied the next place, with 15 ha area out of the total area 70 ha. Its share worked out to about 21%. The old hybrid bred by the public sector, CSH 9, still occupied about 11 ha area. Mahyco 51 covered about 5.5 ha area. JKSH 22 accounted for a little more than three ha area, while Krishi Sanjivini had a little less than 3 ha area. Maha Gujarat 55 and Mahabeej (MSH 296) had 2 ha area and 1.9 ha area respectively. They were closely followed by

Table 27. Allocation of area under different cultivars in Vidarbha region (ha).				
Variety/Hybrid	Area in 2010-11	Area in 2011-12	Area in 2012-13	Pooled
MLSH 296 (Dev Gen)	23.28	24.70	23.28	23.8 (34.1)
ProAgro 8340	14.78	15.59	14.78	15.1 (21.6)
CSH 9	12.96	10.12	10.12	11.1 (15.9)
Mahyco 51	7.29	4.05	5.26	5.5 (8.0)
JKSH 22	5.67	2.02	1.62	3.1 (4.5)
Krishi Sanjivini 296	4.05	2.43	2.02	2.8 (4.1)
Maha Gujarat 55	2.02	2.02	2.02	2.0 (2.9)
Mahabeej (MSH 296)	1.21	2.02	2.43	1.9 (2.7)
Hytech 3201	2.02	1.62	1.62	1.8 (2.5)
CSH 14	1.62	1.21	1.21	1.3 (1.9)
Ajeet 997	1.62	1.62	0.40	1.2 (1.7)
Grand total	76.52	67.41	64.78	69.6 (100.0)

Note: Figures in parenthesis indicate percentage to column total

Hytech 3201 with 1.8 ha area. CSH 14 and Ajeet 997 occupied much smaller area, each one reporting a little more than 1 ha area. These 11 popular hybrids together had 70 ha area under them. Their combined area had fallen from 77 ha in 2010-11 to 65 ha in 2012-13, perhaps due to the intense competition from more remunerative crops. Some other hybrids and varieties may have very small areas under them.

In Marathwada region, there was a larger diversity of 18 cultivars sharing the rainy season sorghum area (Table 28). This region also reported a rapid fall in area under the crop from 153 ha in 2010-11 to 137 ha in 2011-12 and further sliding to 125 ha in 2012-13. MLSH 296 (Dev Gen) had the largest share in area herewith of 23.6%. ProAgro 8340 and JKSH 22 occupied second and third places in terms of area shares. They were closely placed, with the former having 13.2% share and the latter 12.9%. PAC 537 had a share of 8.1%. Mahyco 51 seems to be losing area fast, although it still has an average s hare of 11%. Same is the case with CSH 9, which had an average share of 7.8%. Mahabeej (MSH 296), PAC 501, CSH 14 and Ajeet 997 had shares ranging between 3.8 and 3.1 in the area. Harita 540 followed with a 2.4% share in area. NSH 27 came next with a share of 2.2%, followed by Moti with a 2% share. Each of the remaining five varieties had shares of less than 1%.

The diversity in hybrids and varieties of rainy season sorghum was widest in Western Maharashtra with as many as 22 cultivars (Table 29). In this region, CSH 9 still rules the roost with a maximum share of 20.3% among all the hybrids and varieties. NJH 40 occupied the second place with a share of 11.8%, followed by Mahyco 51 with a 10.8% share. MLSH 296 and JKSH 22 had shares of 9.6% and 9.2% respectively. NSH 18 and ProAgro 8340 had shares ranging between 7 and 6%. Harita 540, MBSH 7, Paras 65 and NSH 27 had shares ranging between 5 and 2%. Other eleven hybrids/varieties like Annapurna, CSH 14, Krishi Sanjivini, Maha Gujarat 55, Hytech 3201, Ajeet 997, KD Pandari 296, Mahabeej (MSH 296), Dhanalaxmi 296 and Ajeet 333 had shares less than 2% each. The total area under rainy season sorghum is declining year after year in Western Maharashtra, but less steeply than in other two regions.

Table 28. Allocation of area under major cultivars in Marathwada region (ha).

Variety/Hybrid	Area in 2010-11	Area in 2011-12	Area in 2012-13	Pooled
MLSH 296 (Dev Gen)	32.19	32.19	33.40	32.6 (23.6)
ProAgro 8340	20.65	19.43	14.78	18.3 (13.2)
JKSH 22	21.26	17.61	14.78	17.9 (12.9)
Mahyco 51 (MSH-51)	21.86	15.38	8.50	15.2 (11.0)
PAC 537	12.55	10.53	10.53	11.2 (8.1)
CSH 9	14.17	10.93	7.19	10.8 (7.8)
Mahabeej (MSH 296)	5.26	4.86	5.67	5.3 (3.8)
PAC 501	4.86	4.86	5.26	5.0 (3.6)
CSH 14	4.05	4.05	5.26	4.5 (3.2)
Ajeet 997	4.05	3.24	5.67	4.3 (3.1)
Harita 540	3.64	2.43	4.05	3.4 (2.4)
NSH 27 (Nuziveedu Seeds)	3.44	2.83	2.83	3.0 (2.2)
MOTI (Yashoda Seed)	2.02	2.83	3.24	2.7 (2.0)
KD Pandari 296	1.21	2.02	0.40	1.2 (0.9)
Kaveri Colonel 6363	0.00	1.62	1.62	1.1 (0.8)
Hytech 3201	0.81	0.81	0.81	0.8 (0.6)
NJH 1175	0.81	0.81	0.81	0.8 (0.6)
Dhanlaxmi 296	0.00	0.40	0.40	0.3 (0.2)
Grand total	152.83	136.84	125.20	138.3 (100.0)

Note: Figures in parenthesis indicate percentages to column total

Table 29. Allocation of area under major sorghum cultivars in Western MH region (ha).

Variety/Hybrid	Area in 2010-11	Area in 2011-12	Area in 2012-13	Pooled
CSH 9	15.18	18.42	18.62	17.4 (20.3)
NJH 40	10.32	10.12	9.92	10.1 (11.8)
Mahyco 51	10.22	9.41	8.10	9.2 (10.8)
MLSH 296	7.69	8.50	8.50	8.2 (9.6)
JKSH 22	11.94	6.07	5.67	7.9 (9.2)
NSH 18	5.67	6.07	6.07	5.9 (6.9)
ProAgro 8340	6.28	6.48	4.25	5.7 (6.6)
Harita 540	6.68	2.23	2.23	3.7 (4.3)
MBSH 7	2.02	3.04	4.86	3.3 (3.8)
Paras 65	2.02	2.02	2.02	2.0 (2.4)
NSH 27	2.63	1.42	1.42	1.8 (2.1)
Annapurna	1.21	1.62	1.62	1.5 (1.7)
CSH 14	0.00	2.43	2.02	1.5 (1.7)
Krishi Sanjivini 296	1.62	1.21	1.21	1.3 (1.6)
Maha Gujarat 55	1.21	1.21	1.21	1.2 (1.4)
Ajeet 997	0.00	1.21	1.82	1.0 (1.2)
Hytech 3201	0.40	1.21	1.21	0.9 (1.1)
Local	0.81	0.81	1.01	0.9 (1.0)
KD Pandari 296	0.81	0.81	0.81	0.8 (0.9)
Dhanlaxmi 296	1.62	0.00	0.00	0.5 (0.6)
Mahabeej (MSH 296)	0.81	0.81	0.00	0.5 (0.6)
Ajeet 333	0.00	0.40	0.40	0.3 (0.3)
Grand total	89.17	85.53	83.00	85.9 (100.0)

Note: Figures in parenthesis indicate percentages to column total

The information on area under different varieties of rainy season sorghum in the three regions is summed over and presented in Table 30. There were a total of 27 hybrids/varieties adopted by the sample farmers in the state of Maharashtra. MLSH 296 (Dev Gen) emerged as the most popular hybrid in the state with a share of 22% in the total area under sorghum. Good old CSH 9 occupied second place with a share of 13.4% of total area. ProAgro 8340 was closely behind with an average share of 13.3%. These three hybrids together held nearly 50% of the total area. Mahyco 51 and JKSH 22 occupied fourth and fifth ranks with shares of 10.2 and 9.8 respectively. These top five hybrids accounted for more than three-fourths of the total area under rainy season sorghum. PAC 537 and NJH 40 had shares between 3 and 4 % each.

Five hybrids, Mahabeej (MSH 296), CSH 14, Harita 540, Ajeet 997and NSH 18, had shares of 2-3% each. Another six hybrids, PAC 501, NSH 27, Krishi Sanjivini 296, Hytech 3201, Maha Gujarat 55 and MBSH 7, had area shares ranging between 1 and 2% each. The remaining nine hybrids and varieties had shares smaller than 1% each. The area decline in rainy season sorghum area is evident even at the aggregate sample level of the state of Maharashtra. The total sorghum (rainy season) area of the sample farmers declined from 319 ha in 2010-11 to 290 ha in 2011-12 and further to 273 ha in 2012-13.

In the village community surveys (FGDs) conducted, progressive farmers and village leaders gave their estimates of area coverage under different sorghum hybrids and varieties. This information was analyzed and is presented in Table 31. These results are at variance with the information collected from the sample farmers. Both these sources of information should be considered together to assess the area coverage by different hybrids. According to village surveys, CSH 9 was the most popular hybrid in terms of area coverage in Vidarbha and Western Maharashtra. Only in Marathwada, was it second to MLSH 296. When the data were pooled from all the three regions, CSH 9 stood first with 19% area coverage in the state. MLSH 296 became quite popular in Vidarbha and Marathwada regions, but lagged behind CSH 9, Mahabeej 7 and Mahyco 51 in Western Maharashtra region. But, it occupied the second position with 18.2% area coverage in the state. Mahyco 51 came third with 10.4% area coverage. Mahabeej 7 figured only in Western Maharashtra and yet it occupied third position with 9.4% area coverage. ProAgro 8340 and JKSH 22 reached fourth and fifth positions among the cultivars with area coverage of 7.4 and 6.0% respectively at the state level. CSH 14 and MSH 296 were the next important hybrids with area coverage of 3.4% each. NSH 18, PAC 537, Harita 540 and Maha Gujarat 55 had area shares ranging between 2 and 3% each. Six varieties occupied between 1 and 2% of the total rainy season sorghum area. The remaining three hybrids accounted for less than 1% area each.

Table 30. Allocation of area under major sorghum cultivars in the total sample (ha).

Variety/Hybrid	Area in 2010-11	Area in 2011-12	Area in 2012-13	Pooled
MLSH 296	63.16	65.38	65.18	64.6 (22.0)
CSH 9	42.31	39.47	35.93	39.2 (13.4)
ProAgro 8340	41.70	41.50	33.81	39.0 (13.3)
Mahyco 51	39.37	28.85	21.86	30.0 (10.2)
JKSH 22	38.87	25.71	22.06	28.9 (9.8)
PAC 537	12.55	10.53	10.53	11.2 (3.8)
NJH 40	10.32	10.12	9.92	10.1 (3.4)
Mahabeej (MSH 296)	7.29	7.69	8.10	7.7 (2.6)
CSH 14	5.67	7.69	8.50	7.3 (2.5)
Harita 540	10.32	4.66	6.28	7.1 (2.4)
Ajeet 997	5.67	6.07	7.89	6.5 (2.2)
NSH 18	5.67	6.07	6.07	5.9 (2.0)
NSH 27	6.07	4.25	4.25	4.9 (1.7)
PAC 501	4.86	4.86	5.26	5.0 (1.7)
Krishi Sanjivini 296	5.67	3.64	3.24	4.2 (1.4)
Hytech 3201	3.24	3.64	3.64	3.5 (1.2)
Maha Gujarat 55	3.24	3.24	3.24	3.2 (1.1)
MBSH 7	2.02	3.04	4.86	3.3 (1.1)
Moti	2.02	2.83	3.24	2.7 (0.9)
Paras 65	2.02	2.02	2.02	2.0 (0.7)
KD Pandari 296	2.02	2.83	1.21	2.0 (0.7)
Annapurna	1.21	1.62	1.62	1.5 (0.5)
Kaveri Colonel 6363	0.00	1.62	1.62	1.1 (0.4)
Local	0.81	0.81	1.01	0.9 (0.3)
Dhanlaxmi 296	1.62	0.40	0.40	0.8 (0.3)
NJH 1175	0.81	0.81	0.81	0.8 (0.3)
Ajeet 333	0.00	0.40	0.40	0.3 (0.1)
Grand total	318.52	289.78	272.98	293.8 (100.0)

Table 31. Extent of adoption of major cultivars based on village community surveys (% area).

Cultivar	VDB	MTW	WMH	Pooled
CSH 9	25.7	13.4	20.4	19.0
MLSH 296	24.0	27.9	8.8	18.2
Mahyco 51	8.0	11.1	10.8	10.4
Mahabeej 7	0.0	0.0	19.8	9.4
Pro Agro 8340	22.7	5.7	2.8	7.4
JKSH 22	4.6	8.8	4.4	6.0
CSH 14	2.6	2.9	4.2	3.4
MSH 296	0.7	9.6	0.0	3.4
NSH 18	0.0	0.0	5.0	2.3
PAC 537	0.0	6.6	0.0	2.3
Harita 540	0.1	2.4	3.0	2.3
Maha Gujarat 55	3.0	0.0	3.4	2.2
NJH 40	0.0	0.0	3.9	1.9
Hytech 3201	0.9	1.1	2.0	1.5
Ajeet 997	0.6	1.8	1.4	1.4
NSH 27	0.6	1.1	1.8	1.3
Rasi 2	0.0	0.0	2.8	1.3
PAC 501	0.0	3.4	0.0	1.2
Ajeet 333	0.0	0.0	1.9	0.9
Krishi Sanjivini 296	3.8	0.0	0.3	0.8
CSH 10	0.0	0.0	1.6	0.7
Others	2.6	4.3	1.8	2.8
Total	100.0	100.0	100.0	100.0

Table 32. Estimates of adoption of improved cultivars by different methods.
(Expert Elicitation vs Focus Group Discussions vs Household survey – comparison across methods)

Cultivar	Expert estimates (%)	Community-level (%)	HH-level pooled (%)
CSH 9	40	19.0	13.9
MLSH 296 (Dev Gen)	NA	18.2	22.2
Mahyco 51	NA	10.4	10.1
Mahabeej 7	NA	9.4	0.0
ProAgro 8340	NA	7.4	13.2
JKSH 22	NA	6.0	9.8
CSH 14	30	3.4	2.5
MSH 296		3.4	0.0
NSH 18	NA	2.3	0.0
PAC 537	NA	2.3	3.8
Nirmal 40 (NJH-40)	NA	0.0	3.4
Harita 540	NA	0.0	2.4
Ajeet 997	NA	0.0	2.3
Other hybrids	10	18.2	16.1
Other OPVs	20	0.0	0.0
Total area under MVs	100.0	100.0	99.7
Area under locals	0.0	0.0	0.3

The study team tried to obtain the estimates of area coverage by different hybrids using three different methods. Plant breeders and Agricultural Department officials were asked to give their expert estimates and their responses were averaged. They are furnished in the second column of Table 32. Experts were of the opinion that about 40% of the area was still covered by CSH 9. The varieties from the sample results is possibly because the expert group belongs to the public sector, and therefore tended to over-estimate the share of CSH 9. They felt further that CSH 14 and MLSH 296 together have a combined share of 30% in rainy season sorghum area. They also estimated that the open pollinated varieties still have a share of 20% and that the remaining 10% area is shared by other hybrids (other than CSH 9, CSH 14 and MLSH 296).

The estimates generated from the focus group discussions were averaged and are presented in the third column of the same table. These groups also gave the first place to CSH 9, with an estimated share of 19%, closely followed by MLSH 296 with a share of 18.2%. The subsequent places were assigned to Mahyco 51, Mahabeej 7, ProAgro 8340, JKSH 22, CSH 14, MSH 296, NSH 18 and PAC 537 in that order. They estimated that the combined share of all other hybrids was 18.2%. They said that the open pollinated varieties and local variety did not occupying any significant area. The estimates generated from the household survey differed from the estimates of the focus groups. These data are given in the last column of Table 32. It was MLSH 296 that emerged as the most popular hybrid with 22.2% coverage. CSH 9 stood second with 13.9%. ProAgro 8340 and Mahyco 51 occupied the third and fourth places with shares of 13.2 and 10.1 respectively. JKSH 22 also had nearly 10% share (9.8%). PAC 537 (3.8%), Nirmal 40 (3.4%), CSH 14 (2.5%), Harita 540 (2.4%) and Ajeet 997 (2.3%) were the other hybrids which were popular in some localities. All other hybrids (not listed out in Column 1) together had a share of 16.1%. While the open pollinated varieties did not have any presence, local variety had a small share of 0.3%. The estimates from household survey are closer to the estimates generated from focus group discussions (FGDs) than those given by the experts. The moral of the comparison of different estimates in Table 32 is that experts can supply only a vague idea of the field situation, but they can be obtained at nominal costs. Focus group discussions which involve some costs, hit the mark closer but are still somewhat inaccurate. Household interviews, which involve substantial cost and time, are required to get a precise picture of the field situation.

Major sources of information and procurement of seeds of improved cultivars

Even in 2012-13, the year in which the study was conducted, hybrid seeds of all the five most popular sorghum hybrids was mainly from the seed dealers (see Table 33). The three hybrids, ProAgro 8340, Mahyco 51 and JKSH 22 were totally supplied to the farmers in all the three regions through seed dealers only. Most of the farmers in all the regions obtained the seeds of MLSH 296 from the seed dealers. Only 5% of the farmers in Vidarbha region obtained seeds from sources other than seed dealers. Even in case of public sector hybrid, CSH 9, all the farmers in Vidarbha and 97% of the farmers in Marathwada obtained the seeds from the seed dealers. Only in the Western Maharashtra region, 46% of the farmers accessed the hybrid seeds of CSH 9 from sources other than the seed dealers. Government sources seemed to have procured them from public sector seed corporations and supplied them to some farmers in Western Maharashtra on subsidy under some special scheme or the other.

Table 33. Major sources of sorghum seeds during 2012-13 (% farmers).

	VDB	MTW	WMH
Cultivars	Seed dealer	Seed dealer	Seed dealer
MLSH 296	95%	100%	100%
CSH 9	100%	97%	54%*
ProAgro 8340	100%	100%	100%
Mahyco 51	100%	100%	100%
JKSH 22	100%	100%	100%

* The remaining farmers in the sample benefitted through govt. program (36%) and other sources (10%)

6.2.3 Average productivity levels across regions

The perceived yields of sorghum by the sample farmers of the three regions under different climatic conditions are averaged and presented in Table 34. In a bad year, sorghum is expected to yield 1156 kg ha^{-1} in Vidarbha region; 1195 kg in Marathwada region and 1224 kg ha^{-1} in Western Maharashtra. The pooled average yields perceived is 1193 kg ha^{-1} of grain and 4790 kg ha^{-1} of fodder. The best yields could go up to 3122 kg ha^{-1} in Vidarbha; 3316 kg ha^{-1} in Marathwada; and 3468 kg ha^{-1} in Western Maharashtra. The pooled average yields for the entire sample are 3306 kg ha^{-1} for grain and 10290 kg ha^{-1} for fodder. But, in a normal year, rainy season sorghum yields would average to 2162 kg ha^{-1} in Vidarbha; 2198 kg ha^{-1} in Marathwada; and 2349 kg ha^{-1} in Western Maharashtra. The pooled average grain yield would be 2227 kg ha^{-1} and that of fodder would be 7620 kg ha^{-1}. The perceived yields are lower in Vidarbha and are highest in Western Maharashtra, with Marathwada occupying an intermediate position.

Of the three latest seasons, the yields were highest in 2010-11, while they were near normal in 2011-12 and below normal in 2012-13 (Table 35). In 2010-11, the season was between a normal year and the best year. The grain yield ranged between 2415 kg ha^{-1} in Vidarbha and 2812 kg ha^{-1} in Western Maharashtra, with Marathwada region reporting an intermediate yield of 2521 kg ha^{-1}. The pooled average yield worked out to 2568 kg ha^{-1} for grain and to 8460 kg ha^{-1} for fodder. The 2011-12 season was near normal with pooled average yields of 2047 kg ha^{-1} for grain and 6940 kg ha^{-1} for fodder. The yields during 2012-13 were below normal, with pooled averages of 1938 kg ha^{-1} for grain and 7120 kg ha^{-1} for fodder. In all the years, the realized average yields were the highest in Western Maharashtra and lowest in Vidarbha, with intermediate yield levels in Marathwada.

Table 34. Average grain and fodder yields under different climatic situations.

	Vidarbha region		Marathwada region		Western MH region		Pooled	
Climate type	Grain*	Fodder**	Grain*	Fodder**	Grain*	Fodder**	Grain*	Fodder**
Bad year	1155.90	4.67	1194.88	4.84	1224.02	4.78	1192.53	4.79
Normal year	2161.94	7.58	2198.44	7.55	2349.24	7.79	2227.12	7.62
Best yield	3122.19	9.99	3316.49	10.32	3467.61	10.53	3306.23	10.29

kg per ha **Tons per ha

Table 35. Average grain and fodder yields for the last three seasons.

	Vidarbha region		Marathwada region		Western MH region		Pooled	
Year	Grain*	Fodder**	Grain*	Fodder**	Grain*	Fodder**	Grain*	Fodder**
2010-11	2415.33	8.32	2521.17	8.55	2811.68	8.43	2567.63	8.46
2011-12	1899.68	6.66	1998.38	7.01	2288.87	7.06	2046.60	6.94
2012-13	1864.71	6.97	1881.50	7.04	2125.57	7.43	1938.37	7.12

kg per ha ** Tons per ha

Table 36. Grain yields (kg ha^{-1}) of major popular hybrids across regions, 2012-13.

Variety/hybrid	Vidarbha	Marathwada	Western Maharashtra	Pooled
CSH 9	1576.7	1714.6	1791.8	1693.9
MLSH 296	1826.6	1927.0	2137.8	1912.5
ProAgro 8340	2209.3	2203.7	4284.1*	2489.6
Mahyco 51	2130.4	2052.0	2094.3	2079.8
JKSH 22	1679.6	1683.1	2404.5	1803.0

* Limited plots were grown

The average grain yields obtained for the five leading hybrids in the three regions of Maharashtra during 2012-13 are summarized in Table 36. Mahyco 51 was the only hybrid that yielded highest in Vidarbha region, when compared to the other two regions. All the other four hybrids reported highest yields in Western Maharashtra. The yield was significantly higher in Western Maharashtra compared to the other two regions, particularly in case of JKSH 22 and ProAgro 8340. From these data, one can conclude that all the varieties yielded higher in Western Maharashtra than in other regions, with the exception of Mahyco 51, which is particularly suitable for Vidarbha.

Yield variability under different climatic conditions

The distributions of perceived and actual yields of rainy season sorghum are plotted and are depicted in three different graphs for the three regions (Figure 21). The plot for the actual yields in 2012-13 corresponded close to the yield distribution perceived for a normal year, although it was slightly flat and to the left of it. The year 2012-13 was a near-normal with a little deficit of performance to an extent of about 5%.

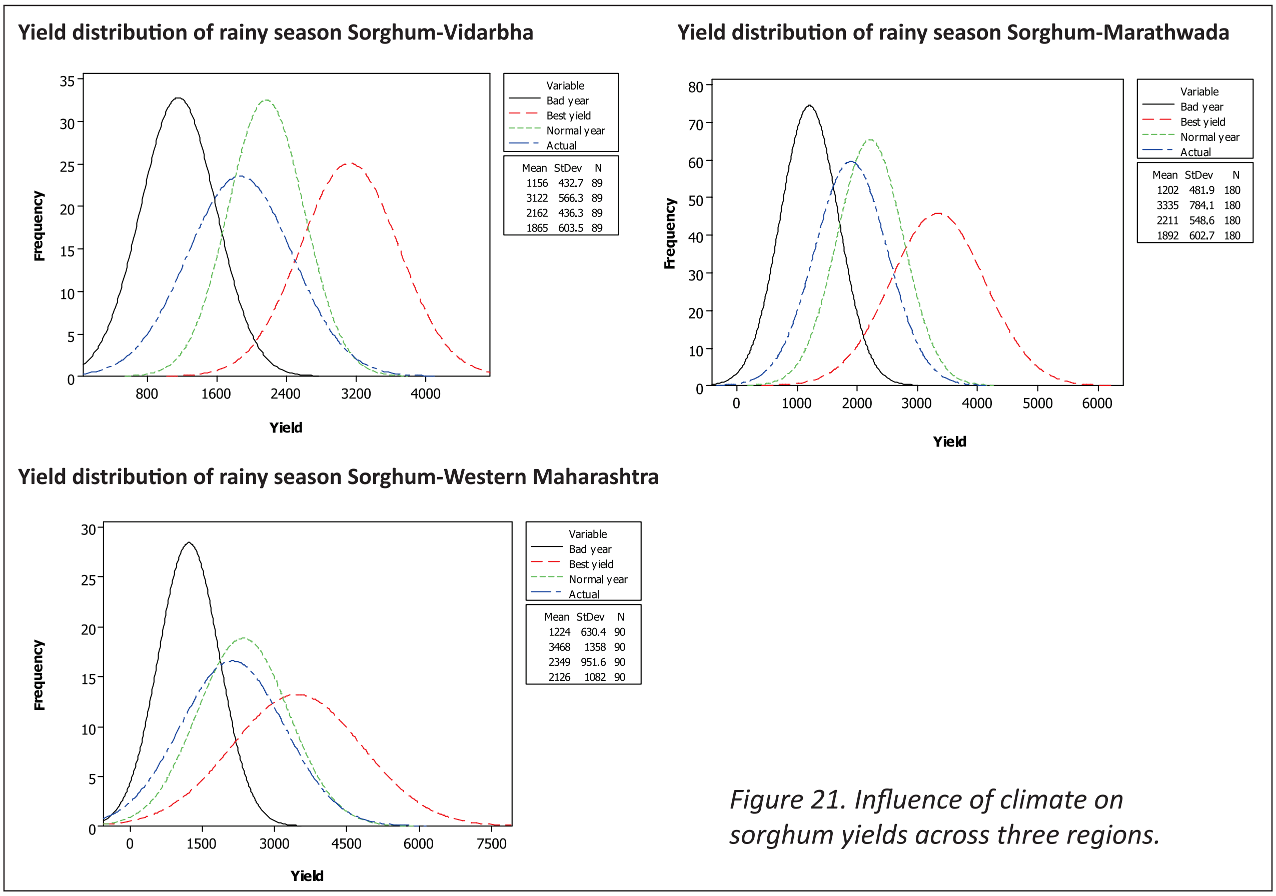


Figure 21. Influence of climate on sorghum yields across three regions.

Yield variability across time, 2010-2012

The yield distributions of rainy season sorghum in the three years, 2010-11 to 2012-13 are graphed in Figure 22. In the case of Vidarbha region, the yield distributions for 2011-12 and 2012-13 were more or less similar, while that of 2010-11 was certainly to the right, indicating higher yields achieved by the sample farmers in that season relative to the two succeeding years. In case of Marathwada and Western Maharashtra regions, higher yields were achieved by the sample farmers in 2010-11 when compared with the next two years. And also, the yields achieved in 2011-12 were slightly better than those in 2012-13 in both regions. All the graphs were close to normal distribution. But seasonal conditions for sorghum were most favorable in 2010-11 in all the regions. While the seasonal conditions were similar in Vidarbha for the two seasons, 2011-12 and 2012-13, they were a shade better during 2011-12 than in 2012-13 in the other two regions.

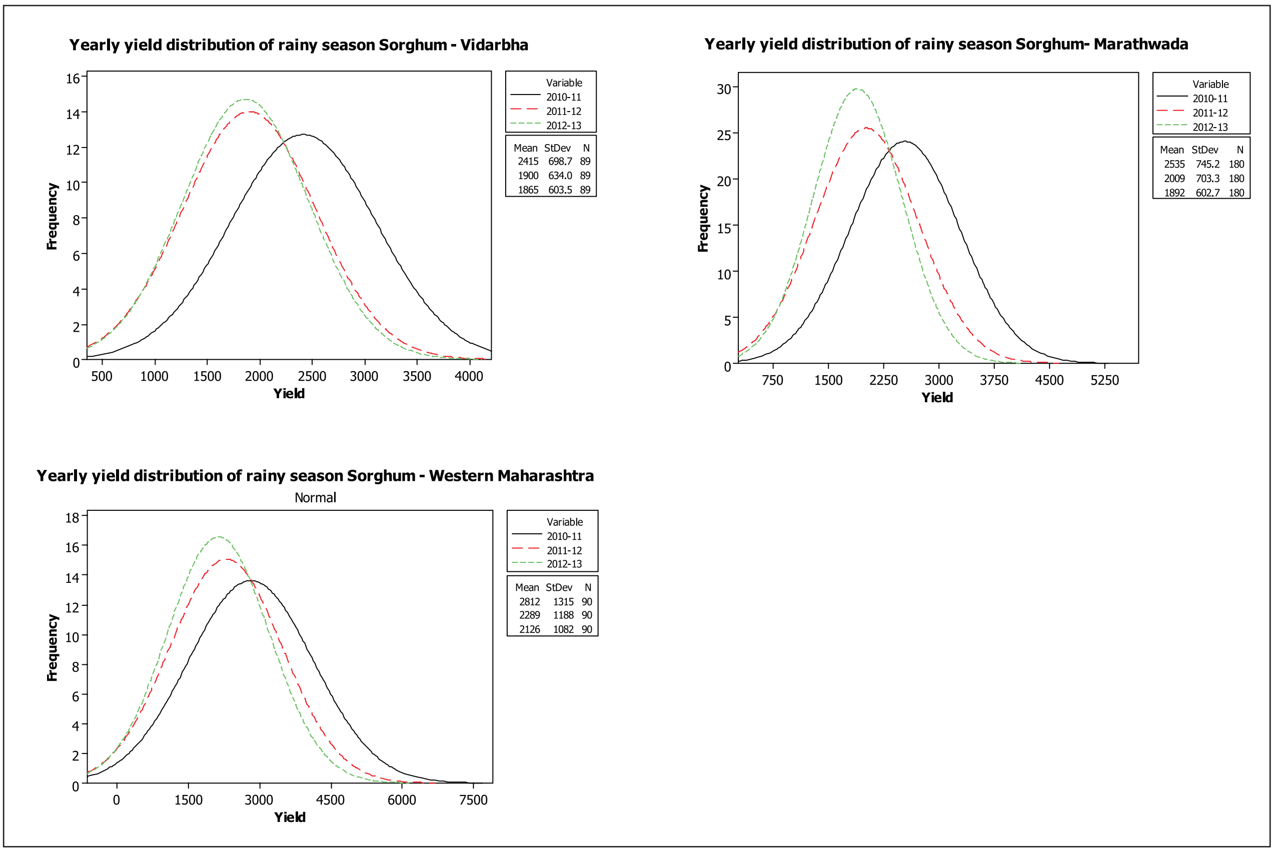


Figure 22. Yield distributions of sorghum across three regions, 2010-11 to 2012-13.

Performance of five popular hybrids in Maharashtra during 2012-13

The yield distributions for the five important hybrids of rainy season sorghum in Maharashtra for 2012-13 are depicted in Figure 23. The distributions for CSH 9 (black), JKSH 22 (orange) and MLSH 296 (red) were leptokurtic and were to the left, indicating lower mean yield. The distributions for ProAgro 8340 (blue) and Mahyco 51 were relatively platykurtic but were to the right of the graphs of other three varieties, indicating higher mean yields. The highest mean yield was reported for ProAgro 8340 in 2012-13.

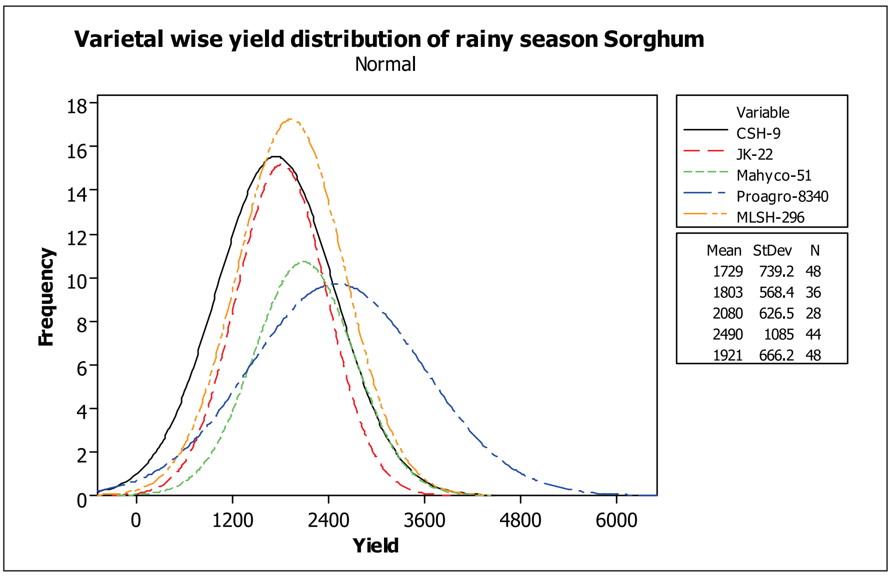


Figure 23 Yield distributions by important hybrids in Maharashtra, 2012-13.

6.2.4 Unit cost reduction due to improved technology

Among the sorghum hybrids, MLSH 296 was the leader with a share of nearly 22% (Table 37). The public sector hybrid, CSH 9 which was released nearly three decades ago still covers 13.4% area. ProAgro 8340, Mahyco 51 and JKSH 22 occupied more than 10% area each. These five hybrids together accounted for 68.7% area. Other major hybrids in contention are PAC 537, NJH 40, CSH 14 and Ajeet 997. All other hybrids had shares of 2% or less in the sorghum area.

Table 37. Major cultivars observed during the 2012-13 HH survey.

Cultivar	Year of release	% area occupied
MLSH 296	1995	22.0
CSH 9	1983	13.4
ProAgro 8340	2001	13.3
Mahyco 51	1982	10.2
JKSH 22	1999	9.8
PAC 537	2003	3.8
NJH 40	1999	3.4
CSH 14	1992	2.5
Ajeet 997	2002	2.2
NSH 18	-	2.0
PAC 501	1998	1.7
NSH 27	-	1.7
Hytech 3201	2007	1.2
MSBH 7	2000	1.1
Local	NA	0.3
NJH 1175	2011	0.3

NJH 1175 recorded the lowest unit cost of production (USD 125/ton) among all the hybrids grown by the sample farmers (Table 38). Next to it, ProAgro 8340, NSH 27 and PAC 537 were the most efficient hybrids with unit costs of production ranging between USD 141-145 per ton of grain after adjusting the costs of cultivation for the fodder value. NJH 40, Mahyco 51 and Hytech 3201 had unit cost of production ranging between USD 154-168. Ajeet 997, CSH 14, CSH 9 and JKSH 22 were also produced at unit costs lower than USD 200 per ton. PAC 501 and NSH 18 had costs of production ranging between USD 204 to 266 per ton. Local was the least efficient with the highest unit cost of production of USD 469 per ton and it was closely followed by MSBH 7.

Since the objective was to judge whether there was a technological shift in production over a period of time, the hybrids were categorized in to two groups, namely, those released/marketed before 2000 and those released/marketed after 2000 based on current spread in the state (Table 39). Eight hybrids fell in the first group and remaining seven in the second group. Further analysis will be done by comparing the performance of these two groups of hybrids.

The gross returns from both the categories were high enough to cover the variable costs and leave some small surpluses (Table 40). Relatively, the returns over variable costs (VC) were higher with the second group of hybrids. When only the variable costs were considered, the cost of production per ton was USD 238.35 with the pre-2000 hybrids, while it was only USD 199.47 for the hybrids released after 2000. The latter group roughly had a 19% advantage over the first group. Similar difference was observed when the total costs of production were considered. The post-2000 hybrids were able to increase the returns over variable costs by lowering the unit costs of production.

Table 38. Costs and returns from major cultivars (USD per ha).

Item	Ajeet-997	CSH-14	CSH-9	Hytec-3201	JKSH 22	Local	Mahyco-51	MSBH-7	MLSH-296	NJH-1175	NJH-40	NSH-18	PAC-501	PAC-537	ProAgro-8340	NSH-27
No of plots	2	7	27	3	15	2	13	4	42	1	2	5	4	5	26	5
Land preparation	58.8	68.8	76.9	61.0	79.5	115.9	73.7	69.8	65.1	89.8	56.4	54.1	69.6	79.9	71.2	66.3
Seed bed preparation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Compost	0.0	0.0	11.6	0.0	19.4	0.0	14.7	53.4	18.0	0.0	0.0	5.6	55.8	0.0	14.1	0.0
Planting	30.3	35.5	32.2	30.5	43.5	35.3	34.1	46.0	30.3	37.1	27.2	27.8	34.1	27.6	36.2	36.9
Seed cost	18.2	14.9	15.5	14.6	16.2	6.7	15.5	15.9	16.1	12.9	16.8	15.1	15.5	15.1	15.7	15.4
Seed treatment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fertilizer cost	71.0	73.3	77.1	62.9	79.8	66.0	78.1	75.3	67.9	93.4	53.9	78.6	89.1	55.5	72.2	66.1
Micro-nutrient	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	68.2	0.0	0.0	0.0	0.0	0.0
Interculture	18.3	35.2	34.5	37.4	42.8	31.2	31.3	40.8	45.9	12.3	19.8	33.7	44.3	58.2	41.2	48.4
Weeding	18.0	36.9	44.0	51.3	37.2	62.0	43.1	38.9	37.5	0.0	55.7	47.2	31.4	38.6	40.3	54.5
Plant protection	0.0	1.6	5.9	7.1	5.9	0.0	2.1	0.0	3.6	0.0	0.0	0.0	0.0	0.0	1.9	8.8
Irrigation	0.0	0.0	0.0	9.2	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	1.2	0.0
Watching	4.8	7.5	12.9	7.6	11.1	25.6	11.6	15.2	5.1	9.0	3.4	4.0	4.5	3.6	10.1	13.0
Harvesting	71.5	83.5	76.1	66.6	89.8	74.1	79.5	72.6	74.2	74.1	84.9	55.0	82.9	74.0	83.8	92.9
Threshing	22.5	29.4	36.0	24.7	38.6	23.3	36.9	23.4	33.0	38.2	45.8	15.1	37.2	30.3	39.6	37.0
Marketing	7.4	10.8	9.7	15.6	13.0	14.1	13.1	19.4	13.5	6.7	9.9	9.6	13.7	20.5	14.1	17.7
Total Variable Cost (VC)	320.7	397.4	433.8	388.6	476.7	454.3	433.8	470.6	410.8	373.6	441.9	345.9	478.3	403.4	441.4	457.1
Fixed cost/ha	314.7	308.3	330.4	322.2	361.0	224.8	304.4	286.5	335.8	314.5	404.6	247.3	364.0	373.0	340.7	359.6
Total cost (TC)	635.4	705.7	764.3	710.8	837.7	679.1	738.2	757.1	746.6	688.1	846.4	593.2	842.2	776.4	782.0	816.8
Grain yield (kg/ha)	1144	1641	1842	1721	1718	709	2022	886	1778	1976	2248	1084	1914	2025	2375	2398
Price (USD/ton)	195	195	197	206	192	291	201	186	192	164	187	196	181	207	199	185
By-product (kg/ha)	4700	4100	4000	4500	4400	3700	4300	2800	4100	4700	4300	2500	4000	4600	5000	5000
Price (USD/ton)	24	23	24	22	33	33	24	25	24	27	22	23	22	24	22	24
Gross returns	336	414	459	454	475	328	510	235	440	451	515	270	434	530	583	564
COP/ton (VC) grain	280	242	236	226	277	641	215	531	231	189	197	319	250	199	186	191
COP/ton (VC) Fodder	68	97	108	86	108	123	101	168	100	79	103	138	120	88	88	91
COP/ton (VC) grain-fodder	182	185	183	168	193	469	163	452	176	125	154	266	204	145	140	141

COP: Cost of Production

Table 39. Categorization of major cultivars (> 2000/<2000).

Cultivar	Year of release	Category -1/2
Local	NA	NA
CSH 14	1992	1
CSH 9	1983	1
Mahyco 51	1982	1
JKSH 22	1999	1
MSBH 7	2000	1
MLSH 296	1995	1
NJH 40	1999	1
PAC 501	1998	1
Ajeet 997	2002	2
Hytech 3201	2007	2
NJH 1175	2011	2
NSH 18	*	2
PAC 537	2003	2
ProAgro 8340	2001	2
NSH 27	*	2

* Not known but believed to be after 2000
Category 1: before 2000; Category 2: after 2000.

Table 40. Relative performance of old and new category cultivars (USD per ha).

	Old cultivars (<2000)	New cultivars (>2000)
Activity	114 plots	47 plots
Land preparation	71.2	69.0
Seed bed preparation	0.0	0.0
Compost/animal penning	17.5	8.4
Planting	33.9	33.9
Seed cost	15.8	15.5
Seed treatment	0.0	0.0
Fertilizer cost	73.9	70.2
Micro-nutrient	1.5	0.0
Interculture	38.6	41.1
Weeding	39.7	41.3
Plant protection	3.9	2.4
Irrigation	0.2	1.3
Watching	8.9	8.7
Harvesting	73.4	78.8
Threshing	34.7	34.0
Marketing	12.5	14.3
Total Variable Cost (TVC)	425.7	418.9
Fixed cost/ha	333.0	333.3
Total Cost (TC)	759	752
Grain yield (kg/ha)	1786	2100
Price (USD/ton)	194	198
By-product (kg/ha)	4100	4700
Price (USD/ton)	25	23
Gross returns/ha	449	524
COP/ton (VC)*	238.35	199.47
COP/ton (TC)*	424.97	358.09

* for grain production only; COP: Cost of Production

Table 41 also compared the unit costs of production of different hybrids when only the variable costs were considered. The weighted average costs of production were computed for the two categories of hybrids, using weights for area coverage. When all the costs of production were assigned to grain production (assuming zero value for fodder), the unit costs of production dropped by USD 31.1 per ton of grain as we moved from old to new hybrids. If sorghum was grown for fodder purpose alone (assuming zero value for grain), the unit costs of production for fodder fell by USD 14.5 per ton of fodder. In the more realistic scenario, the fodder value was subtracted from the costs of cultivation and the unit costs of production of grain were computed. The unit costs of production fell USD 27 per ton when the old hybrids were replaced by the new hybrids. These set of figures were used for the computation of welfare benefits.

6.2.5 Quantification of research benefits

The parameters that will be used in the welfare estimation model are specified for important rainy season sorghum growing districts in Maharashtra (see Table 42). The first two rows represent the production and consumption of rainy season sorghum in these districts. The farm gate price was taken as USD 272 per ton as reported by the Directorate of Economics and Statistics, Government of Maharashtra. The elasticity of supply was assumed at 0.5% while the elasticity of demand considered was -0.2%. It was assumed that it would take nine years to develop a hybrid (ie, from 1993 to 2002) and that it would take three years till the seed is produced and marketed (2005), taking the total time lag between initiation of research and adoption to be 12 years. It was further assumed that the adoption would reach the ceiling level over the next nine years (ie, 2013). The total time lag between initial research and ceiling level of adoption was

Table 41. Unit cost reductions due to new improved technology (USD per ton).

Cultivars	Category (<2000/ >2000)	% area covered in 2012-13	COP/ton over VC for grain	COP/ton over VC for stover	COP/ton over VC*	Weighted adoption	Weighted COP/ton over grain	Weighted COP/ton over stover	Weighted COP/ton over VC*
Pre-2000 cultivars									
CSH 14	1	2.5	242.2	96.9	184.7	3.9	9.4	3.8	7.2
CSH 9	1	13.4	235.5	108.5	183.4	20.9	49.2	22.7	38.3
JKSH 22	1	9.8	277.5	108.3	193.0	15.3	42.4	16.6	29.5
Mahyco 51	1	10.2	214.5	100.9	163.5	15.9	34.1	16.1	26.0
MSBH 7	1	1.1	531.2	168.1	452.1	1.7	9.1	2.9	7.8
MLSH 296	1	22	231.0	100.2	175.7	34.3	79.3	34.4	60.3
NJH 40	1	3.4	196.6	102.8	154.5	5.3	10.4	5.5	8.2
PAC 501	1	1.7	249.9	119.6	203.9	2.7	6.6	3.2	5.4
		64.1	272.3	113.2	213.9	100.0			
Post-2000 cultivars									
Ajeet 997	2	2.2	280.3	68.2	181.7	9.0	25.2	6.1	16.3
Hytech 3201	2	1.2	225.8	86.4	168.3	4.9	11.1	4.2	8.2
NJH 1175	2	0.3	189.1	79.5	124.8	1.2	2.3	1.0	1.5
NSH 18	2	2	319.1	138.4	266.1	8.2	26.0	11.3	21.7
PAC 537	2	3.8	199.2	87.7	144.7	15.5	30.9	13.6	22.4
ProAgro 8340	2	13.3	185.8	88.3	139.5	54.3	100.9	47.9	75.7
NSH 27	2	1.7	190.6	91.4	140.6	6.9	13.2	6.3	9.8
		24.5	227.1	91.4	166.5	100.0			
					UCR	Category-1	240.7	105.0	182.7
						Category-2	209.6	90.5	155.7
						Difference	31.1	14.5	27.0

VC* : Variable cost after deducting the fodder value generated per ha

Table 42. Parameters used in quantification of research benefits.

Parameter	Akola	Amravati	Beed	Dhule	Hingoli	Jalgaon	Latur	Nanded	Parbhani	Sangli	Satara	Osmanabad	Yavatmal	Rest of MH
Sorghum production ('000 tons)	75.7	23.5	30.1	32.4	43.7	173.4	132.4	110.1	68.4	70.7	76.6	37.4	54.0	246.2
Sorghum consumption ('000 tons)	34.4	21.3	13.7	14.7	19.8	78.7	60.1	50.0	31.1	32.1	34.8	17.0	24.5	766.1
Farm gate price (USD/ton)##	272	272	272	272	272	272	272	272	272	272	272	272	272	272
Elasticity of supply	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Elasticity of demand	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Research lag (years)	9	9	9	9	9	9	9	9	9	9	9	9	9	9
Years from start of the project to start of the adoption (years)*	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Initial adoption lag (years)**	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Years from start of the project to maximum adoption (years)	21	21	21	21	21	21	21	21	21	21	21	21	21	21
Ceiling level of adoption (proportion)	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Unit cost reduction (USD/ton)	27	27	27	27	27	27	27	27	27	27	27	27	27	27

* Both public and private sectors started research in 1993 (Improved cultivars were released in 2001). These cultivars assumed to reach ceiling level by 2013. Assumed to generate the welfare benefits up to 2022.

* * From release of cultivars to initial adoption

Based on Maharashtra Agricultural Statistics, 2012-13

estimated at 21 years. Since hybrid sorghums were fully adopted, the ceiling level of adoption reached 100%, giving a proportion of one. The unit cost reduction by shifting from pre-2000 to post-2000 hybrids was by USD 27 per ton of sorghum grain. The study also assumed that the adoption of improved sorghum hybrids would sustain for another nine more years (ie, up to 2022). Thus, the present study made an attempt to estimate the total welfare benefits accrued between 1993 and 2022 in the state.

The total production of rainy season sorghum in 2012-13 was estimated as 1.198 million ton. The equlibrium condition required the assumption that all the production was consumed (see Table 43). The total welfare gain from improved sorghum technology was estimated at USD 150.0 million between 1993 and 2022. Since sorghum faces inelastic demand (-0.2), it was much lower than the supply elasticity. Due to this reason, only 28% of the total benefits were appropriated by the producers, leaving the remaining 72% benefits to the consumers. Since the adoption was universal, all these benefits accrued to the adopters.

Table 44 summarizes the regional-wise break-up of the total welfare benefits from rainy season sorghum hybrid technology in Maharashtra during 2012-13. The data clearly indicates that the producers in the three regions benefited significantly because of sorghum technology while the 'rest of MH' derived the huge chunk of welfare benefits through consumers. At aggregated level in the state, around 28.5% of the total benefits were accrued through producer gains and the remaining 71.5% due to consumers' gains in the state. Among the three regions, the highest total benefits were estimated in Marathwada region followed by Western Maharashtra and Vidarbha regions. The farmers who adopted the sorghum technology derived the maximum benefits due to peak-level of adoption of improved cultivars in the state. The non-adopter losses were at the lowest level in the state.

The disaggregation details of total welfare benefits in the state are summarized in Table 45. Because of the ceiling level of adoption of rainy season sorghum technologies in the state, the losses due to non-adopters farmers was at the minimal level. The sorghum producer farmers benefited through reduction in unit cost of production while the sorghum consumers in the state enjoyed per unit lower output prices. Further, the detailed break-up of welfare benefits for each study district are summaried in appendix 5.

Table 43. Direct welfare estimates due to improved cultivars in Maharashtra.

Welfare benefits	Value
Total production ('000 tons)	1198.3
Consumption at farm household level ('000 tons)	1198.3
Total welfare change	150.0#
Producer surplus	42.8#
Consumer surplus	107.2#
Adopters	43.1#
Non-adopters	-0.3#

#USD million

Table 44. Welfare benefits across regions and Maharashtra (USD million).

Type	MH Total	VDB#	MTW#	WMH#	Rest of MH@
Total research benefits	149.98	16.44	29.49	27.11	76.94
Producer gains	42.81	7.68	13.75	12.67	8.70
Consumers gains	107.17	8.76	15.74	14.44	68.24
Adopters benefits	43.12	7.74	13.86	12.76	8.77
Non-adopters losses	-0.32	-0.06	-0.10	-0.09	-0.06

includes the sample districts only (see Appendix -1)
@ includes the 21 non-sampled districts in Maharashtra

Table 45. Dis-aggregation of welfare benefits (USD million).			
Type	Total MH benefits	Benefits due to non-adopters	Benefits due to adopters
Total welfare change	149.98	-0.31	150.30
Producer surplus	42.81	-0.32	43.12
Consumer surplus	107.17	0.00	107.17

6.2.6 Competitiveness of rainy season sorghum

Table 46 summarizes the competitiveness of rainy season sorghum across three regions and the state as a whole. The competitiveness of sorghum was assessed in comparison with other major crops existed in that region. Soybean and cotton crops are severely competing with sorghum during rainy season in all the three regions. Among all crops, soybean performed well in terms of net margins per ha. It was followed by cotton, pigeonpea and groundnut crops. Economically, sorghum crop performed very badly in all the three regions. This situation clearly illustrates the causes for substitution of sorghum by other competing crops and decline in cropped area over time. The detailed break-up of item-wise costs of cultivation of sorghum and other competing crops are furnished in appendix 6.

Table 46. Competitiveness of rainy season sorghum across regions (USD per ha).

Crop name	TVC/ha	TC/ha	GR/ha	NR over TC	NR over VC
Vidarbha region					
Sorghum	395.4	738.4	449	-289	54
Soybean	445.7	797.7	1197	399	751
Cotton	610.8	936.4	1164	227	553
Green gram	279.9	667.6	408	-260	128
Marathwada region					
Sorghum	417.8	762.5	453	-309	35
Soybean	465.7	824.9	1224	400	759
Cotton	688.6	1055.2	1327	271	638
Pigeonpea	441.9	760.0	1158	398	716
Western MH region					
Sorghum	473.4	777.1	536	-241	63
Cotton	676.1	1037.5	1232	194	556
Groundnut	872.6	1182.5	1216	34	556
Pearl millet	360.5	585.0	414	-171	53
Pooled Maharashtra					
Sorghum	426.9	760.4	471	-290	43.9
Soybean	471.5	824.8	1209	385	737.9
Cotton	671.0	1028.7	1274	245	603.1

TVC: Total variable costs
TC : Total costs
GR : Gross returns
NR over TC: Net returns over total costs
NR over VC: Net returns over total variable costs

6.3 Facilitating factors

The drivers of rainy season sorghum technology adoption across regions in the state, sorghum farmers' access to formal credit, and their perceptions on agricultural intensification and sustainability were captured during the primary survey. These details are analyzed and summarized in the following sub-sections:

6.3.1 Role of networks in diffusion of technology

The network of friends was found to be most powerful network, with virtually every sample farmer having friends who influenced him (Table 47). 95% of the farmers relied on friends to acquire and share information on technology. They also lead in credibility with 44% of the sample farmers trusting the information obtained from friends. 73% of the sample farmers are connected to relatives and 51% of them share/acquire information from them. But only 4% of them trust the information obtained from the relatives, implying that very low credibility is attached to that information. Next network in importance is the cooperative in which 51% of the sample farmers are members. But only 8% obtain information from it and only 5% trust it. For these reasons, relatives and cooperatives are not dependable sources of information about technology. About 41% are members of the self-help groups but this network is not relied for accessing information. Among other informal networks, krishimitras are the next most useful ones to acquire information. About one-third of the sample is member of these groups and most of them access information from them and as many as 27% rely on them. The panchayat is considered an important network by many but only 8% get information from it, but hardly 1% of the sample trusts it. About 20% are the members of farmers' clubs and 18% of the sample obtains information through it. This also has high credibility with 14% of the sample trusting it. Caste groups are important sources of information, but they also have low credibility. Thus, friends, krishimitras and farmers' clubs are the important sources of technology with a fairly high credibility. Other networks are not useful either due to poor reach or lack of credibility.

6.3.2 Credit access to sample households

Formal credit is important in all the three regions and, relatively, more so in Western Maharashtra (Table 48). However, the loan amount per farmer is enough to meet the expenses of rainy season crop cultivation, with an average of USD 460 per farmer. About one half of the loan taken is outstanding. This proportion is even higher in Vidarbha, where 64% of the loan taken is outstanding. The interest rate ranged from 2% to 18% per year.

The dependence on informal credit is very low in Maharashtra (Table 49). It is totally absent in Western Maharashtra and relatively higher in Vidarbha. In the overall sample, the average loan taken is USD 20 per HH and about one-fourth of the amount is outstanding. The interest rates are about the same as formal credit. The informal borrowings are just enough to meet the immediate credit requirements of household, not for any special purpose.

Table 47. Various informal networks as primary sources of information.

Network type	% HH member in this network	% HH use this network to share/acquire information	% HH believe this network
SHGs	40.6	3.6	4.2
Krishimitra	33.9	31.1	26.9
Cooperative	50.6	8.1	5.0
Farmer club	19.7	18.1	13.9
Caste group	15.0	13.1	3.1
Relative	72.8	51.1	3.9
Friends	99.7	95.0	43.9
Panchayat	29.7	7.5	1.4

Table 48. Formal credit availed by sample farmers, 2012-13.

Item	Vidarbha	Marathwada	Western Maharashtra	Overall
Amount (USD/HH)	420	410	580	460
Purpose	Agriculture	Agriculture	Agriculture	Agriculture
Interest rate (%)	2 - 12.5	2 – 15	4 – 18	2 – 18
Outstanding amount	270	220	220	230

Table 49. Informal credit availed by sample farmers, 2012-13.

Item	Vidarbha	Marathwada	Western Maharashtra	Overall
Amount (USD/HH)	4	30	-	20
Purpose	Agriculture	Agriculture	-	Agriculture
Interest rate (%)	3	3 – 15	-	3 - 15
Outstanding amount	4	9	-	5

6.3.3 Perceptions about agricultural intensification and sustainability

The sample farmers perceived good benefits due to sorghum technology (Table 50). They perceived that the yields have gone up by 8-10% in all the regions, with an average increase of 9%. It is significant that 280 out of 360 sample farmers perceived yield increase of that order. They perceived that the fodder yield has also gone up by 14%. 80-83% have perceived that the grain and fodder quality have also improved. About 41% felt that the crop duration has decreased, facilitating higher cropping intensity. Almost 86% of the respondents felt that the new varieties are more resistant to diseases like grain mold. About 72% felt that the new varieties are even more tolerant to insect pests. About 86% opined that the new varieties are more tolerant to drought, perhaps due to reduced duration. Surprisingly the respondents reported that they could reduce 60% of sorghum area and yet meet their family requirements. Since the grain and fodder yield increased by only 9-14%, this heavy reduction in area should have been either due to reduction in family requirements or due to loss of profitability from sorghum cultivation.

Table 50. Farm-level benefits of sorghum technology compared to a decade ago.

	Area-wise break-up			
Type of benefit	VDB (N=90)	MTW (N=180)	WMH (N=90)	Pooled (N=360)
Percentage increased grain yield/ha	8.6 (74)	8.3 (133)	10.0 (73)	8.8 (280)
Percentage increased fodder yield/ha	12.6 (78)	13.5 (166)	15.0 (77)	13.6 (321)
% overall household welfare position increased	8.8 (45)	8.5 (90)	8.0 (23)	8.5 (158)
Better grain quality (Yes)	(71)	(152)	(74)	(297)
Better fodder quality (Yes)	(67)	(148)	(73)	(288)
Reduced duration leading to higher cropping intensity (Yes)	(31)	(83)	(35)	(149)
Resistance to diseases (grain mold)*	406.5 (73)	361.6 (162)	104.5 (75)	310.0 (310)
Resistance to pests (Shoot fly, Aphids)*	350.8 (60)	375.4 (137)	83.2 (61)	300.6 (258)
Tolerance to drought*	353.5 (77)	332.7 (165)	100.8 (69)	286.4 (311)
Reduction in sorghum area for meeting family needs due to higher yield (% area reduced per HH)	66.5 (40)	64.0 (94)	45.4 (45)	59.9 (179)

Figures in the parenthesis indicate no. of households
* yields per ha improved or saved to new technology

The perceptions about agricultural sustainability ring some danger bells about agricultural sustainability in the study areas (Table 51). 91% felt that the livestock population has decreased. 82% opined that the fodder/grazing resources have decreased. 54% felt that the area allocation to food crops has decreased. 79% believed that the average size of holding has decreased. 88% agreed that the application of organic manures like farm yard manure has decreased. 95% are concerned that the soil fertility status is dwindling. 92% considered that the soil erosion is increasing. 84% indicated that the use of inorganic fertilizers is increasing. 27% believed that the use of micro-nutrients is increasing. 71% of the respondents felt that the use of plant protection chemicals is on the rise. All these indicators threaten agricultural sustainability in Maharashtra. On the up-side, about 16% felt the use of green manure crops is increasing. 69% opined that land use intensity is increasing. 54% believed that the use of legume crops in crop rotation is increasing. Similarly, 53% argued that the investments for soil and water conservation are increasing. These are all positive features contributing to agricultural sustainability. But, the net effect seems to be endangering agricultural sustainability and food security in Maharashtra as well as in the country.

Table 51. Perceptions of sample farmers about agricultural sustainability (N=360).

	Pooled (% of HH)		
Indicator	Increased	Constant	Decreased
Livestock population (no. per HH)	1.7	7.8	90.6
Availability of fodder/grazing pastures	0.8	17.5	81.7
Area under green manure crops	16.4	81.4	2.2
Land allocation for food crops (ha)	0.6	45.0	54.4
Average landholding size of farm (ha)	1.4	19.2	79.4
Land-use intensity (no. of crops per year)	69.2	30.0	0.8
Use of legumes in crop-rotations /inter-cropping	54.2	16.4	29.4
FYM/other organic matter application rate (Q/ha/year)	3.6	8.1	88.3
Soil and water conservation investments per acre (private and public)	53.3	46.4	0.3
Soil loss due to erosion	91.9	2.8	5.3
Soil fertility status (organic carbon and NPK levels)	0.3	5.0	94.7
In-organic fertilizers (N, P, K – application rate)	83.6	12.8	3.6
Micro-nutrient application (kg/ha)	26.7	73.1	0.3
Frequency of soil testing and use of fertilizers based on recommendations	24.7	75.0	0.3
Expenditure on plant protection chemicals (Rs/ha)	71.1	26.7	2.2
Expenditure on farm mechanization (Rs/ha)	100.0	0.0	0.0

I-Increased; C- Constant; D- Decreased

7. Summary and Conclusions

Maharashtra is the most important state for sorghum in India. The rainy season sorghum area, which stood at 2.68 m ha in the triennium of 1966-68, has dropped to 0.79 m ha in the quinquennial of 2010-14. As the productivity increased from 636 to 1262 kg ha^{-1} in the same period, the fall in production was moderated. It recorded 1.71 m tons in the triennium of 1966-68 but it dropped to 1.0 m tons by 2010-14. The top 13 sorghum growing districts in the rainy season accounted for 84.6% and 79.5% of production in the state. Since, the 13 selected districts account for the bulk of rainy season sorghum area and production, the present study is restricted to them only.

While the decline of rainy season sorghum was partly caused by the development of irrigation facilities and shift in consumer preference for fine cereals like rice and wheat, it was exacerbated by policy bias against coarse cereals such as sorghum in the country. The public investment and input subsidy policy, which involves heavy subsidies, was loaded in favor of superior cereals like rice and wheat. Out of the total input subsidies, rice alone accounted for 46%. At the other extreme, the support was less than 1% for the coarse grains like sorghum, pearl millet, finger millet etc. In the fixation of minimum support prices also, there was a discrimination against the coarse grains. Even the lower support prices of coarse grains like sorghum were not backed up by procurement, even when the market prices fell below them.

Indian Institute of Millets Research (IIMR) has done pioneering work in the development of high yielding varieties and hybrids. The International Crops Research Institute for the Semi-Arid Tropics, which was set up in 1972, has the global mandate for collection and preservation of sorghum germplasm and development of varieties and hybrids suitable for different sorghum growing areas in the world. In 2000, ICRISAT also established a Hybrid Parents Research Consortium for sorghum in which several private sector companies joined by paying a specified membership fee and are getting A, B and R lines for the development of hybrids suitable to rainy season sorghum in different states.

The households surveyed were predominantly male headed and the average age of household head was around 45 years. They had about 20 years of farming and they were growing rainy season sorghum since 19 years. In the household composition, males outnumbered females, indicating an adverse sex ratio. Most of the households had agriculture as the main occupation and incomes were more diversified in Western Maharashtra sample than in other regions. The weighted average size of holding in the pooled sample was 3.16 ha, with 0.78 ha under irrigation and the remaining area under rainfed condition.

The asset value of the sample farmers was the highest in case of Marathwada sample followed by Western Maharashtra and Vidarbha. The asset value of an average household in the pooled sample was USD 98,000. The net income of an average household in the pooled sample was USD 3440 per year or USD 1.81 per person per household. The consumption expenditure per household per year in the pooled sample was USD 1330, which is equivalent to USD 0.7 per capita per day. Since the World Bank defines all the persons spending less than USD 1.0 per day as very poor, the sample farmers growing rainy season sorghum in Maharashtra fall in the category of very poor.

MLSH 296 emerged as the most popular hybrid with 22% cropped area coverage in the state. CSH 9 stood occupied second place with 14%. ProAgro 8340 and Mahyco 51 registered the third and fourth places in the state. The estimates of household survey are closer to the estimates generated from focus group discussions than those given by the expert opinions.

Out of the 15 hybrids that prominently figured in the study, eight were released before 2000, and they were grouped under category 1, while the seven other hybrids released after 2000, were grouped under category 2. The crucial question was whether the new hybrids released after 2000 were more productive than the other group. If they were more productive, it would result in the reduction of the unit cost of production. Weighted average costs of production per ton were computed for both category 1 and category 2 hybrids. The weighted average unit cost of production was USD 183 for category 1 hybrids and USD 156 for category 2 hybrids, suggesting a unit cost reduction of USD 27 per ton as we move from category 1 to category 2 hybrids. Using this value in the formulae, the total welfare gain for Maharashtra due to technical change was calculated as USD 150 million between 1993 and 2022.

In the pooled sample, the benefit/cost ratio was 0.6 for rainy season sorghum, while cotton with 1.2 and soybean with 1.5 were far more profitable. In all the regions, rainy season sorghum recovered the variable costs and had some small surplus, but it could not recover a part of the fixed costs due to which the benefit/cost ratio remained below 1.0. Sorghum in the postrainy season also recorded a benefit/cost ratio of 0.7, which was at par with 0.7 of wheat, but was lower than 1.2 of chickpea. Thus, sorghum in both the seasons failed to recover all the costs in Maharashtra.

Among the networks with which the sample farmers are connected, friends, krishimitra groups and farmers' clubs turned out to be the most useful ones providing information on new technologies to the farmers. They relied more on formal sources for credit rather than on informal sources. Almost all the sample farmers perceived benefits from improved sorghum production technology in the rainy season. More than three-fourths of the sample perceived that the grain yield has increased due to new hybrids by about 9%.

Most of the respondents perceived the benefits from rainy season sorghum production technology in definite terms. However, they expressed concerns about the long-term sustainability of the production technology in view of aggravating indicators with negative impacts on sustainability. The study has demonstrated that the research and development system was able to deliver better technologies which had deep impacts on welfare. The adoption was total and the impact was high even when the rainy season crop is non-remunerative and is fast losing area. It underlines the need for development of even better technologies in the face of climate change and prospects for the revival of coarse cereals in the future. Of course, technology is only the necessary condition for revival, but the necessary conditions must be ensured by policy support or by reversal of adverse policies against coarse cereals.

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Appendixes

Appendix 1

Region-wise rainy season sorghum cultivating major districts in Maharashtra state		
S.no	District	Region
1	Beed	Marathwada
2	Hingoli	Marathwada
3	Latur	Marathwada
4	Nanded	Marathwada
5	Parbhani	Marathwada
6	Dhule	Western Maharashtra
7	Jalgaon	Western Maharashtra
8	Sangli	Western Maharashtra
9	Satara	Western Maharashtra
10	Akola	Vidarbha
11	Amravati	Vidarbha
12	Osmanabad	Vidarbha
13	Yavatmal	Vidarbha

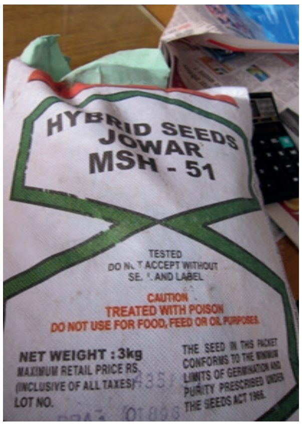
Appendix 2

Randomization procedure for selection of mandals for primary survey

Mandal	District	Rainy season sorghum area ('000 ha)	Cumulative total	Scale to cumulative total	Add random no. (0.56)	Int. differences
Akola	Patur	7632.2	21575.0	0.49	1.05	1
Amravati	Warud	5273.4	66569.2	1.51	2.07	1
Beed	Kaij	12332.4	119491.2	2.70	3.26	1
Dhule	Shirpur	7409.8	158318.0	3.58	4.14	1
Hingoli	Aundha	10373.4	200686.8	4.54	5.10	1
Jalgaon	Muktainagar	6942.6	241902.4	5.48	6.04	1
Jalgaon	Rawer	11034.2	288215.4	6.52	7.08	1
Latur	Devani	6329.8	330032.0	7.47	8.03	1
Latur	Latur	13594.8	385787.6	8.73	9.29	1
Latur	Nilanga	18628.4	422367.0	9.56	10.12	1
Nanded	Bhokar	7912.8	464897.4	10.52	11.08	1
Nanded	Hadgaon	14141.2	508723.2	11.52	12.08	1
Nanded	Mukhed	24532.8	569883.6	12.90	13.46	1
Parbhani	Sonpeth	8551.8	598719.0	13.55	14.11	1
Parbhani	Parbhani	11636	640630.2	14.50	15.06	1
Sangli	Khanapur	22928	695810.2	15.75	16.31	1
Satara	Karad	9353.6	735512.4	16.65	17.21	1
Osmanabad	Umarga	15116.2	784397.8	17.76	18.32	1
Osmanabad	Kalamb	16826.8	817454.6	18.50	19.06	1
Yavatmal	Pusad	6611.8	860283.4	19.47	20.03	1

Appendix 3:

Photographs of major rainy season sorghum improved cultivars in Maharashtra



Bhagya Lakshmi – 296 (Mahabeej)

Appendix 4: Minimum dataset details and assumptions

Research lag (years)

This very important parameter was estimated via detailed discussions with research groups and careful review of many documents and varietal release information. Details are again provided in the later sections.

Adoption parameters

Adoption lag; Years from research start to start of adoption; Years from release of the new technology to start of adoption; Years from research start to ceiling level of adoption; and Maximum adoption.

This set of parameters is very important and they have a major impact on the level of benefits. They are also important in drawing implications about the impact of the technology. Information was enhanced by the extensive survey and the detailed discussions with crop improvement scientists at ICRISAT and NARS partners.

Unit cost reduction

Estimation of this crucial parameter was a very elaborate activity. Full details are discussed in the survey and analytical sections.

Elasticity of supply and demand

These were taken from past studies conducted at an all-India level.

Discount rateThe standard accepted discount rate of 5% was used.

Research cost

This study considers the impact of improved cultivars released from the early 1980s till now, developed by both public and private sources. Hence, the cost estimates for development of improved cultivars and their corresponding dissemination costs would be very difficult. However, concerted efforts are in place to innovatively quantify the cost estimates for all improved cultivars.

Appendix 5: Sample district-wise break-up welfare benefits (USD millions)

Parameter	MH	Akola	Amravati	Beed	Dhule	Hingoli	Jalgaon	Latur	Nanded	Parbhani
Total research benefits	149.98	5.8	3.6	2.3	2.5	3.3	13.3	10.2	8.4	5.3
Producer gain	42.81	2.7	1.7	1.1	1.2	1.5	6.2	4.8	3.9	2.5
Consumers gain	107.17	3.1	1.9	1.2	1.3	1.8	7.1	5.4	4.5	2.8
Adopters benefits	43.12	2.7	1.7	1.1	1.2	1.6	6.3	4.8	3.9	2.5
Non-adopters losses	-0.32	-0.02	-0.01	-0.01	-0.01	-0.01	-0.05	-0.03	-0.03	-0.02

Parameter	Parbhani	Sangli	Satara	Osmanabad	Yavatmal	Rest of MH
Total research benefits	5.3	5.4	5.8	2.9	4.2	76.9
Producer gain	2.5	2.5	2.7	1.3	1.9	8.7
Consumers gain	2.8	2.9	3.1	1.5	2.2	68.2
Adopters benefits	2.5	2.6	2.7	1.4	2.0	8.8
Non-adopters losses	-0.02	-0.02	-0.02	-0.01	-0.01	-0.06

Appendix 6: Competitiveness of sorghum across regions

The economics of the four most important crops of the rainy season in Vidarbha region were computed for 2012-13 season and are presented in Table A1. The total cost of cultivation of sorghum worked out to USD 738 per ha, but the gross returns from this crop were only USD 449 per ha, implying a loss of USD 289 per ha. But if only the variable costs are considered, which is the right criterion in the short run, it gave a small surplus of USD 54 per ha. However, it gave a benefit/cost ratio of only 0.6. Green gram gave a surplus of USD 128 per ha after meeting the variable costs and also gave the same benefit/cost ratio of 0.6, because of low gross returns and high fixed costs relative to variable costs. The two other crops, soybean and cotton, were able to return both the variable and fixed costs and gave net returns of USD 399 and USD 227 per ha respectively. Soybean gave the highest benefit/cost ratio of 1.5, followed by cotton which yielded a benefit/cost ratio of 1.2. Due to such high returns, soybean and cotton are gaining area at the expense of sorghum in the rainy season in Vidarbha region.

The performance of rainy season sorghum in Marathwada region was no different from its performance in Vidarbha region (Table A2). Its total cost of cultivation was USD 763 per ha, but the gross returns from it were only USD 453 per ha, giving a net loss of USD 309 per ha. But it could recover the variable costs and leave a small surplus of USD 35 per ha. It yielded a benefit/cost ratio of 0.59, which would discourage farmers from growing it again. In contrast to sorghum, all the three competing crops recovered all the costs and gave net profits. Both the pulse crops, soybean and pigeonpea, gave high benefit/cost ratios of 1.48 and 1.52 respectively. While the net return was marginally higher in case of soybean, the benefit/cost ratio was slightly higher for pigeonpea. Cotton gave a net return of USD 271 per ha and a benefit/cost ratio of 1.26. This poor performance of sorghum explains why it is losing area year after year in the Marathwada region.

The performance of rainy season sorghum in Western Maharashtra region was a shade better than that in the other two regions, but was the same qualitatively (Table A3). It could not recover all the costs and gave a small surplus of USD 63 per ha after recovering the variable costs. It gave a benefit/cost ratio of 0.7, which would not inspire farmers to grow it again. Pearl millet, which is a poor cousin of sorghum, also gave the same benefit/cost ratio. Its cost of cultivation was lower, but the gross returns were also equally lower. Groundnut crop could just recover the costs and earn a marginal surplus of USD 34 per ha. Its benefit/cost ratio was not different from 1.0. Among all the crops grown in the rainy season, cotton was the only crop which gave some appreciable net returns of USD 154 per ha and clocked a benefit/cost ratio of 1.2. The performance of rainy season crops was quite discouraging in Western Maharashtra region, with sorghum and pearl millet incurring losses, groundnut just breaking even and cotton giving only small profits.

Table A1. Costs and returns of rainy season crops in Vidarbha region, 2012-13 (USD per ha).				
Activity	Sorghum 44 Plots	Soybean 23 Plots	Cotton 16 Plots	Green gram 6 Plots
Land preparation	63.1	60.3	67.7	70.4
Seed bed preparation	0.0	0.0	0.0	0.0
Compost/animal penning	7.0	41.5	59.8	15.3
Planting	29.9	28.3	27.4	20.7
Seed cost	15.1	72.1	65.8	27.6
Seed treatment	0.0	0.1	0.0	0.0
Fertilizer cost	69.5	66.7	121.5	46.8
Micro-nutrient	0.0	0.0	0.4	0.0
Interculture	40.3	30.3	43.7	16.5
Weeding	37.1	31.1	34.7	28.6
Plant protection	3.6	24.1	60.6	7.4
Irrigation	0.0	0.0	8.3	0.0
Watching	6.5	0.0	0.0	0.6
Harvesting	77.8	52.1	112.8	33.6
Threshing	33.2	31.6	0.0	9.5
Marketing	12.3	7.5	8.2	2.9
Total Variable Cost (VC)	395.4	445.7	610.8	279.9
Fixed cost/ha	343.0	352.1	325.6	387.7
Total Cost (TC)	738.4	797.7	936.4	667.6
Grain yield (kg/ha)	1855	1950	1623	605
Price (USD/ton)	189	602	717	664
By-product (kg/ha)	4100	1100	0	300
Price (USD/ton)	24	21	0	20
Gross returns/ha	449	1197	1164	408
Net returns over TC	-289	399	227	-260
Net returns over VC	54	751	553	128
Benefit/Cost Ratio	0.6	1.5	1.2	0.6

Table A2. Costs and returns of rainy season crops in Marathwada region, 2012-13 (USD per ha).

Activity	Sorghum 88 Plots	Soybean 46 Plots	Cotton 49 Plots	Pigeonpea 6 Plots
Land preparation	72.9	65.6	74.0	48.0
Seed bed preparation	0.0	0.0	0.0	0.0
Compost/animal penning	14.8	46.9	35.5	0.0
Planting	35.1	27.3	28.0	31.2
Seed cost	16.1	69.2	70.9	28.6
Seed treatment	0.0	0.4	0.0	0.0
Fertilizer cost	69.4	68.5	155.2	87.7
Micro-nutrient	0.0	0.0	0.4	0.0
Interculture	43.7	35.3	54.6	46.4
Weeding	33.1	37.0	41.3	75.0
Plant protection	2.9	20.2	63.1	40.8
Irrigation	0.4	2.5	11.3	0.0
Watching	7.3	0.2	0.3	0.0
Harvesting	78.0	53.4	142.1	52.2
Threshing	32.3	31.2	0.0	23.9
Marketing	11.9	8.0	11.9	8.1
Total Variable Cost (VC)	417.8	465.7	688.6	441.9
Fixed cost/ha	344.7	359.2	366.6	318.1
Total Cost (TC)	762.5	824.9	1055.2	760.0
Grain yield (kg/ha)	1801	2019	1858	1527
Price (USD/ton)	192	598	714	752
By-product (kg/ha)	4300	900	0	300
Price (USD/ton)	25	19	0	33
Gross returns/ha	453	1224	1327	1158
Net returns over TC	-309	400	271	398
Net returns over VC	35	759	638	716
Benefit/Cost Ratio	0.59	1.48	1.26	1.52

Table A3. Costs and returns of rainy season crops in Western MH region, 2012-13 (USD per ha).

Activity	Sorghum 47 Plots	Cotton 21 Plots	Groundnut 5 Plots	Pearl millet 4 Plots
Land preparation	76.4	83.0	110.7	55.9
Seed bed preparation	0.0	0.0	0.0	0.0
Compost/animal penning	18.3	75.8	111.5	8.1
Planting	32.6	32.7	52.7	45.0
Seed cost	15.3	61.4	177.1	9.7
Seed treatment	0.0	0.0	0.0	0.0
Fertilizer cost	80.6	126.4	74.5	64.7
Micro-nutrient	3.6	4.3	0.0	0.0
Interculture	39.7	45.7	49.0	5.1
Weeding	55.4	49.2	81.2	64.7
Plant protection	4.8	48.2	0.0	0.0
Irrigation	2.6	15.9	5.4	0.0
Watching	14.0	0.4	52.3	0.0
Harvesting	76.5	123.0	97.8	62.9
Threshing	39.1	0.0	49.1	33.5
Marketing	14.8	10.0	11.2	10.8
Total Variable Cost (VC)	473.4	676.1	872.6	360.5
Fixed cost/ha	303.7	361.4	309.9	224.5
Total Cost (TC)	777.1	1037.5	1182.5	585.0
Grain yield (kg/ha)	2000	1704	1344	1410
Price (USD/ton)	213	723	862	245
By-product (kg/ha)	4400	0	1800	3800
Price (USD/ton)	25	0	32	18
Gross returns/ha	536	1232	1216	414
Net returns over TC	-241	194	34	-171
Net returns over VC	63	556	344	53
Benefit/Cost Ratio	0.7	1.2	1.0	0.7

Even in the analysis of the pooled sample, sorghum could just recover the variable costs (Table A4). There was a net loss of USD 290 per ha and the benefit/cost ratio was only 0.6. Soybean gave the best performance with a net return of USD 385 per ha and a benefit/cost ratio of 1.5. Cotton was also profitable, but with a net return of only USD 245 per ha and a benefit/cost ratio of 1.2. Both soybean and cotton are gaining area in Maharashtra at the expense of sorghum in the rainy season. The economics of these three crops in Maharashtra illustrate the causes for changing area allocations.

Table A4. Costs and returns of rainy season crops in pooled sample (USD per ha).

Activity	Sorghum 179 Plots	Soybean 74 Plots	Cotton 86 Plots
Land preparation	71.4	64.0	75.0
Seed bed preparation	0.0	0.0	0.0
Compost/animal penning	13.8	45.2	49.9
Planting	33.1	27.9	29.0
Seed cost	15.6	70.8	67.6
Seed treatment	0.0	0.3	0.0
Fertilizer cost	72.4	76.3	141.9
Micro-nutrient	1.0	0.0	1.3
Interculture	41.8	33.6	50.4
Weeding	39.9	36.1	42.0
Plant protection	3.6	21.7	59.0
Irrigation	0.9	2.7	11.9
Watching	8.8	0.1	0.3
Harvesting	77.6	53.1	132.0
Threshing	34.3	31.7	0.0
Marketing	12.8	7.9	10.8
Total Variable cost (VC)	426.9	471.5	671.0
Fixed cost/ha	333.5	353.3	357.7
Total Cost (TC)	760.4	824.8	1028.7
Grain yield (kg/ha)	1866	1979	1777
Price (USD/ton)	197	601	717
By-product (kg/ha)	4300	1000	0
Price (USD/ton)	24	20	0
Gross returns/ha	471	1209	1274
Net returns over TC	-290	385	245
Net returns over VC	43.9	737.9	603.1
Benefit/Cost Ratio	0.6	1.5	1.2

The costs and returns of the postrainy season crops in Maharashtra are summarized in Table A5. During 2012-13, chickpea was the only postrainy season crop that could recover all the costs and earn a small profit of USD 136 per ha. It gave a benefit/cost ratio of 1.2. Sorghum and wheat failed to recover all the costs and incurred losses. They could just recover the variable costs and leave some small surplus. Both of them gave the same benefit/cost ratio of 0.7. The performance of postrainy season sorghum was not significantly different from that of rainy season sorghum. Although it fetched higher prices for both grain and fodder than in the rainy season, the yields were lower and the gross returns fell short of the costs. Wheat crop also failed to recover the costs due to low yields achieved under rainfed conditions.

Table A5. Costs and returns of postrainy season crops in pooled sample (USD per ha).

	Chickpea 58 Plots	Postrainy-sorghum 30 Plots	Wheat 24 Plots
Land preparation	54.1	70.1	59.7
Seed bed preparation	0.0	0.0	1.7
Compost/animal penning	1.4	7.0	7.8
Planting	30.4	36.8	25.8
Seed cost	96.7	11.9	51.5
Seed treatment	0.0	0.0	0.0
Fertilizer cost	62.4	75.9	87.6
Micro-nutrient	0.0	0.0	0.0
Interculture	8.5	31.2	7.2
Weeding	20.8	32.1	26.4
Plant protection	14.6	0.2	2.7
Irrigation	3.4	1.3	42.9
Watching	0.5	7.6	0.8
Harvesting	53.4	76.9	65.6
Threshing	26.0	32.4	29.2
Marketing	8.2	11.7	8.1
Total Variable Cost (VC)	380.5	395.1	417.1
Fixed cost/ha	344.1	305.4	360.2
Total Cost (TC)	724.5	700.5	777.3
Grain yield (kg/ha)	1334	1552	2033
Price (USD/ton)	645	260	277
By-product (kg/ha)	30	3800	10
Price (USD/ton)	2	28	0.5
Gross returns/ha	860	510	563
Net returns over TC	136	-191	-214
Net returns over VC	480	115	146
Benefit/Cost Ratio	1.2	0.7	0.7

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