Research Report No 71
ICRISAT Research Program Asia

Pearl Millet Technology
Adoption and Impact Study in Maharashtra

D Kumara Charyulu, D Moses Shyam, Cynthia Bantilan, ST Borikar, SK Gupta and KN Rai

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INTERNATIONAL CROPS RESEARCH
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Citation: Kumara Charyulu D, Moses Shyam D, Bantilan Cynthia, Borikar ST, Gupta SK and Rai KN. 2016. Pearl Millet Technology Adoption and Impact Study in Maharashtra. Research Report 71. Patancheru 502 324. Telangana, India: International Crops Research Institute for the Semi-Arid Tropics. 76 pp.
ISBN 978-92-9066-581-6

Acknowledgment

The authors are highly thankful to the CGIAR Research Program (CRP) on Policies, Institutions and Markets (PIM) and the Bill & Melinda Gates Foundation (BMGF) for providing the financial support to undertake this research activity. We sincerely acknowledge the technical support and guidance provided by Dr K Purna Chandra Rao, Former Principal Scientist (VLS), ICRISAT in implementation of this activity. Authors are also thankful to anonymous reviewers of the report for sparing their valuable time and providing the constructive suggestions. Our special thanks are to Dr SP Wani, Director, Research Program on Asia and Dr KV Raju, Theme Leader on Policy and Impact for their motivation and encouragement for bringing this manuscript into existence. Last but not least, we owe all the 360 respondent farmers for their cooperation during the surveys, their warm hospitality and for sparing their valuable time for us.

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This work has
been undertaken
as part of the

CGIAR RESEARCH PROGRAM ON Policies, Institutions and Markets

ICRISAT INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS

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Abbreviations

AICPMIP	All-India Coordinated Pearl Millet Improvement Program
COP	Cost of Production
FAO	Food and Agricultural Organization
FHP	Farm Harvest Prices
FCDS	Food Characteristic Demand System
IFPRI	International Food Policy Research Institute
IMPACT	International Model for Policy Analysis of Agricultural Commodities and Trade
MH	Maharashtra
MPKV	Mahatma Phule Krishi Vidyapeeth
MSP	Minimum Support Price
MTW	Marathwada
NARP	National Agricultural Research Project
NFSA	National Food Security Act
NSSO	National Sample Survey Organization
OPV	Open Pollinated Variety
PDS	Public Distribution System
QUAIDS	Quadratic Almost Ideal Demand System
UCR	Unit Cost Reduction
WMH	Western Maharashtra

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Executive summary

The area under pearl millet cultivation in Maharashtra is concentrated in nine districts, and together they have more than 90% share in area and production of pearl millet. The coverage of pearl millet area in Maharashtra by improved cultivars was near total. In this background, the present study was taken up to assess the adoption of hybrids and improved varieties and their impact on the incomes and living standards of farmers through a detailed survey of 360 sample households drawn from 60 villages belonging to 20 *tehsils* from nine districts. The sample for the field survey was concentrated in Nashik, Ahmednagar and Beed districts, with lower allocations to Aurangabad, Pune, Dhule, Jalgaon, Sangli and Satara districts. Three-fourths of the sample farmers belonged to Western Maharashtra (WMH) region and the remaining one-fourth to the Marathwada (MTW) region. The field survey was carried out during 2013 and the household data pertained to the cropping year 2012-13.

The sample farmers were largely drawn from the middle-aged group, having 25 years of experience in farming and pearl millet cultivation. The households were invariably headed by males, who had about 7.5 years of education. The family size was between 5 (MTW) and 5.5 (WMH). Farming was their main occupation, with supplementary income earned from livestock. The average size of landholding as well as irrigation coverage were higher in MTW, as a result of which, they had more asset values as well than those from WMH. In the pooled sample, pearl millet accounted for 41% of the rainy season cropped area and 30.4% of the total cropped area.

In the aggregate 2012-13 adoption data, ICTP 8203 retained its top place with 27.6% area allocated to it. Mahyco 204 occupied the second place with 18% area coverage. Pioneer 86 M 33 secured third place with 14.6% area. Pioneer 86 M 32, Dhaanya 7872, MLBH 308, Panchaganga 510, Mahyco 163, GK 1044, Nirmal 9 and Varun 666 were the other major hybrids adopted in the state. All the remaining hybrids together accounted for the remaining 11.8% of the area under pearl millet. The average adoption lag observed among major pearl millet improved cultivars was around nine years. The weighted average cost of production of pre-2000 released varieties was USD 182.1 per ton. It was higher than that for the post-2000 released varieties (USD 156.0) by USD 26.1 per ton. The supply curve has shifted to the right and the unit cost of production has fallen by more than 10%. The welfare gains were estimated at USD 103.3 million during 30 years ie, between 1993 and 2022, using the *ex-post* framework developed by Bantilan et al. (2013). Out of these welfare gains, farmers could appropriate only USD 29.5 million, leaving the rest to the consumers of pearl millet. Since only 20% of pearl millet produced in Maharashtra was consumed in Maharashtra, a good part of the consumers' surplus was appropriated by consumers in the rest of India.

The sample farmers perceived that the grain yield, fodder yield, grain and fodder quality have improved due to improved technologies and that it has, in turn, improved their over well-being. The technology also resulted in reduced crop duration and increased resistance to pests, diseases and drought. Overall, it may be concluded that the new technology in pearl millet production has been widely adopted by the farmers of Maharashtra and it has impacted positively on yields, incomes, welfare of households, and sustainability of farming.

1. Introduction

Pearl millet (*Pennisetum glaucum* (L) R.Br.emend.Stuntz) is an important food crop in areas with low rainfall and shallow soils. Being short in duration, it is the most drought-tolerant cereal grown in the arid and semi-arid regions of the world (Bhagavatula et al. 2013). It is the sixth most important food cereal in the world. Globally, the area under millets displayed a declining trend after 1973, reaching 31.4 million ha by 2014-15 compared to 43 million ha in 1961-62 (see Figure 1). But the production showed an increasing trend and touched 35 million tons in 2003 but over the last 54 years it has again fallen back to the starting level of 28 million tons. Productivity increased from 600 kg ha^{-1} in 1961 up to 965 kg ha^{-1} in 2008, but declined to about 903 kg ha^{-1} in 2014-15 (FAOSTAT 2016). At least, productivity growth has ensured that the production did not fall despite a regular decrease in the area under millets.

Pearl millet is one of the most important sources of staple food and fodder in the predominantly rainfed areas of the country. Its grain has very high nutritive value for human consumption and livestock also relish its straw, both in fresh and dried forms. Pearl millet area marginally declined from 9.02 million ha in 1950-51 to about 7.31 million ha by 2014-15 in India. But its production increased from 2.6 million tons in 1950-51 to 9.18 million tons in 2014-15. This rapid increase was possible because of trebling of productivity from 288 kg ha^{-1} in 1950-51 to 1255 kg ha^{-1} in 2014-15. It is largely a rainfed crop, except when it is grown as a summer irrigated crop. Overall, only 10% of the pearl millet area is irrigated in India. A rapid increase in pearl millet yield was possible because of the introduction of hybrids in all the regions, perhaps with the exception of West Rajasthan where landraces/OPVs are still grown due to an extremely risky production environment. During the last six decades, the consumption preferences of human beings turned from health and nutrition towards taste and convenience. 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 (PDS) 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. 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 ₹ 3 kg^{-1}; wheat at ₹ 2 kg^{-1}; and coarse grains like pearl millet at 1 kg^{-1} (The National Food Security Act (NFSA) 2013). In the face of dwindling production 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 ₹ 1 kg^{-1} appears to be difficult.

In the light of changing global and domestic scenarios of pearl millet with respect to area, utilization and policies, a need was felt to study in depth, the situation of pearl millet in heartland such as Maharashtra state of India to find ways of enhancing pearl millet area of cultivation and productivity through a planned survey. The major objectives of the study are: 1) To assess the cultivar-specific adoption estimates in the state through a representative household survey 2) To quantify the impact of improved pearl millet cultivars on the farm yields and accrued welfare benefits to society 3) To estimate the competitiveness of pearl millet cultivation with other competing crops 4) To understand the role of household networks and perceptions of farmers on agricultural intensification and sustainability etc.

With these broad objectives in mind, the present study was carried out systematically, using both primary and secondary sources of information. The comprehensive report is organized into seven sections for better clarity and brevity of results. Section 1 highlights the importance of pearl millet globally and in India. Section 2 summarizes the performance of pearl millet in India, major states and study districts of Maharashtra. The historical development trend of pearl millet improved cultivars and government policy bias against coarse cereals are reviewed and presented in Section 3. The details about sampling framework and methodology used for quantification of welfare benefits are furnished in Section 4. Section 5 details the field reconnaissance survey, primary household survey, data collection and data validation etc.

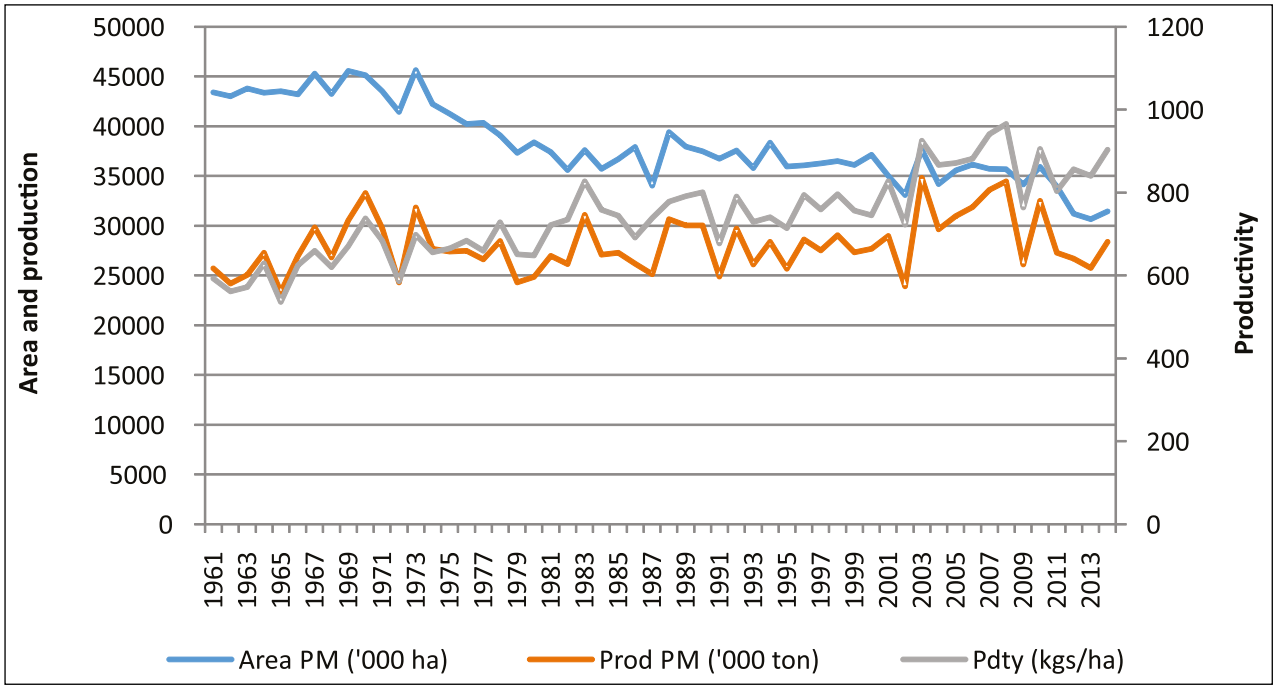

Figure 1. Global trends in area, production and productivity of millets, 1961-2014.
Source: FAOSTAT, 2016

The key findings emanated from the study are summarized in Section 6. The summary and conclusions are discussed in Section 7.

2. Performance of pearl millet

2.1. Pearl millet at the all-India level

In 1970-71, the area under pearl millet was 12.91 million ha and it started steadily declining over the next four decades to reach 7.31 million ha in 2014-15 (Table 1). The area under pearl millet in India has decreased by 15.78% even during the recent period between 2010-11 and 2014-15. But, over the four-and-a-half decades, the production of pearl millet has registered a small increase of 1.15 million tons. In fact, it decreased by 0.69 million tons in the decade between 1970-71 and 1980-81. It remained below the 1970-71 level till 2000-01. But during 2010-11 to 2014-15, it registered an increase of 6.6%. However, productivity dropped only in the first decade (1970-71 to 1980-81) and recovered in the next two decades. It grew by 27% during the recent period between 2010-11 and 2014-15. Irrigation coverage increased from 4% in 1970-71 to 8.3% in 2010-11. Although figures for 2014-15 are not available, they must be higher because of the increasing practice of growing summer pearl millet in several states (GOI 2016).

Table 1. Performance of pearl millet in India, 1970-2015.

Item	1970-71	1980-81	1990-91	2000-01	2010-11	2014-15
Pearl millet area (million ha)	12.91	11.66	10.48	9.83	8.68	7.31
Pearl millet production (million tons)	8.03	5.34	6.89	6.76	8.61	9.18
Productivity (kg ha^{-1})	622	458	658	688	991	1255
Share of area under irrigation (%)	4.00	5.50	5.10	8.00	8.3	NA

Source: Department of Agriculture and Cooperation, GOI, 2016

The area, production and productivity details of pearl millet at the all-India level from 1970-71 to 2014-15 are plotted in Figure 2 in blue, maroon and green colors respectively. Pearl millet area reached a peak in 1972-73 (about 14 million ha) but has shown a declining trend since then. By 2014-15, it reached to a level of 7.31 million ha. Despite the fall in area, the production of pearl millet increased from 8.03 million tons in 1970-71 to more than 9.18 million tons in 2014-15. The production of pearl millet did touch a peak of 12 million tons in 2003-04, but dropped later due to a steep fall in area. Then again, there was a rapid growth in productivity of the improved hybrids/varieties and other production technologies. Productivity of pearl millet also increased by 82% during the last one-and-a-half decades.

The sharp rise in production despite decreasing area is due to a consistent increase in productivity due to better varieties/hybrids and other improvements in cultivation practices. The productivity figures for different years are mapped and a trend line was fitted as shown in Figure 3. The productivity also peaked in 2003-04, crossing 1100 kg per ha. Even in 2014- 15, it was around 1255 kg ha^{-1}. It represents more than a doubling of pearl millet yield between 1970-71 and 2014-15. The trend line fitted to the productivity data is a fairly good fit, as it explained about 73% variability in productivity. It also gave a prediction that the productivity of pearl millet has been increasing at the rate of 17 kg ha^{-1} per year between 1970-71 and 2014-15.

Figure 4 shows decadal trends in productivity of pearl millet at the all-India level. These linear decadal trends are poor fits of the data. Productivity marked a declining trend during the 1970s, but registered positive trends in the next three decades. During 1970s HB3 succumbed to downy mildew and the crop was endangered. This might be one of the reasons for declining trend during 1970s. But, owing to poor and non-significant trend equations, nothing can be concluded firmly about the productivity trends in the decadal periods.

2.2. Performance in major states

In terms of area under pearl millet, Rajasthan stands out as the number one state, with a share of about 57% in the country's area during 2011-15 (quinquennial average). Uttar Pradesh comes a distant second with a share of about 11.2%. Maharashtra, Gujarat and Haryana occupy the next three places with shares of 10%, 8.5% and 6% respectively. These five states together had a share of 93% in the total area. However, Rajasthan accounted for only 44% of the pearl millet production in the country, since it achieved productivity level of only 918 kg ha^{-1} (see Table 2).

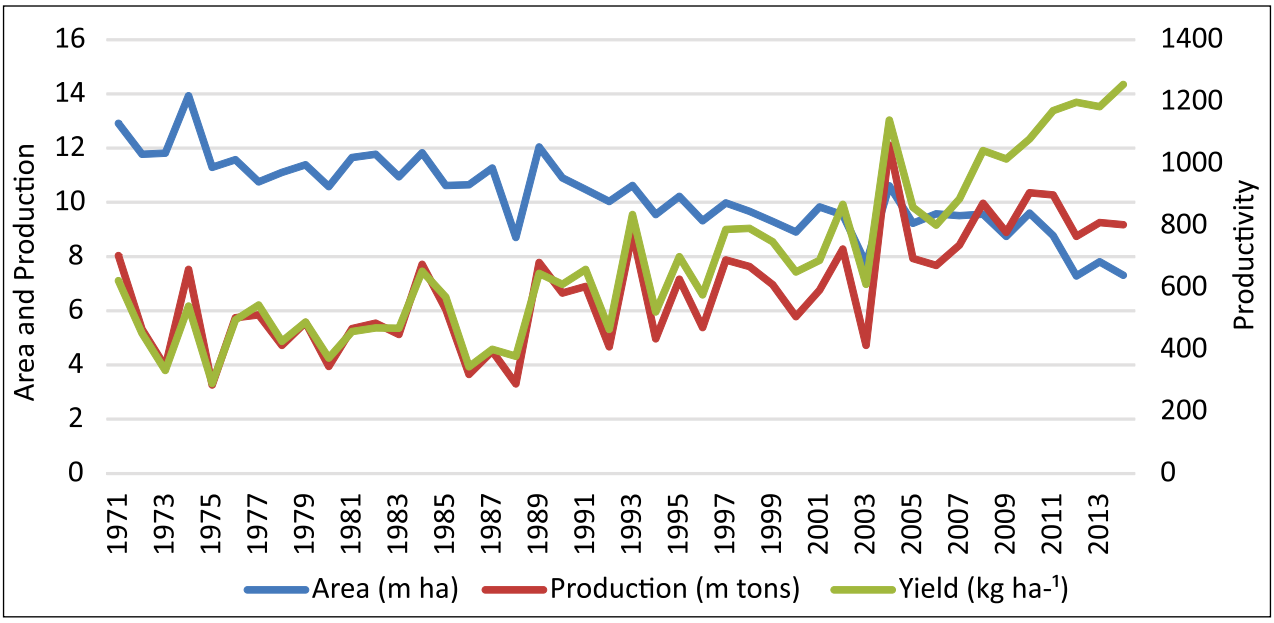

Figure 2. Performance of pearl millet in India, 1971-2014.
Source: Ministry of Agriculture, India

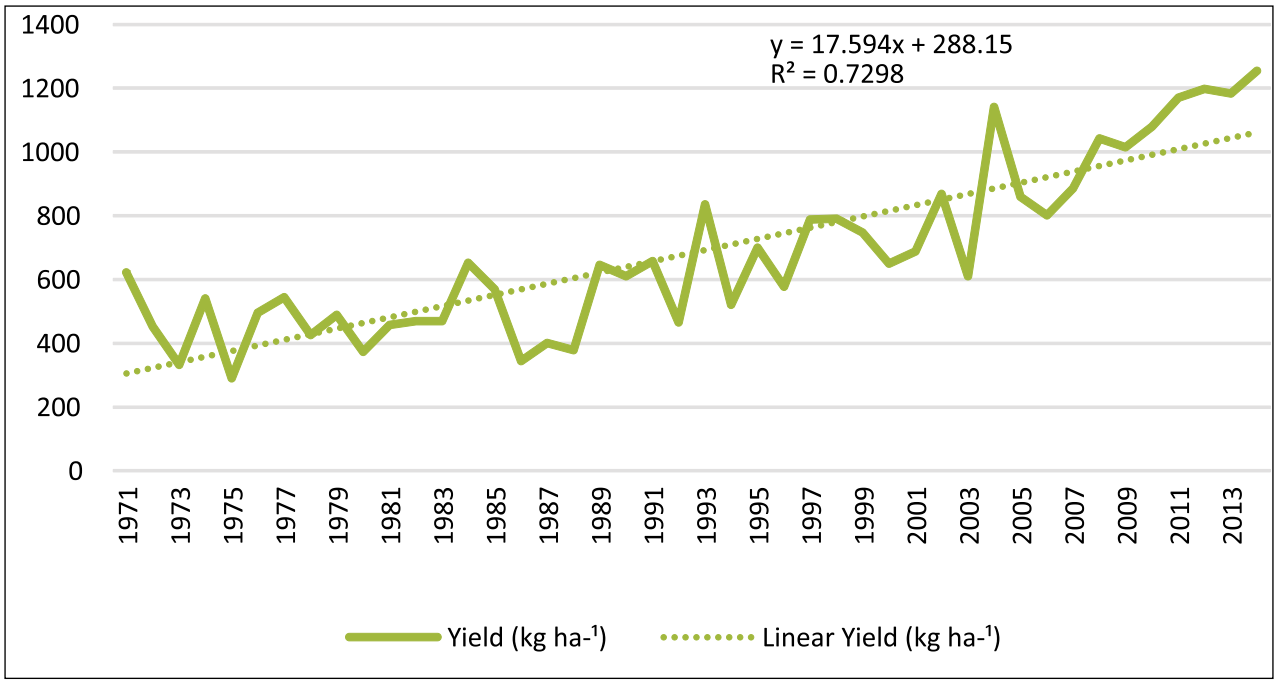

Figure 3. Productivity of pearl millet in India, 1971-2015.

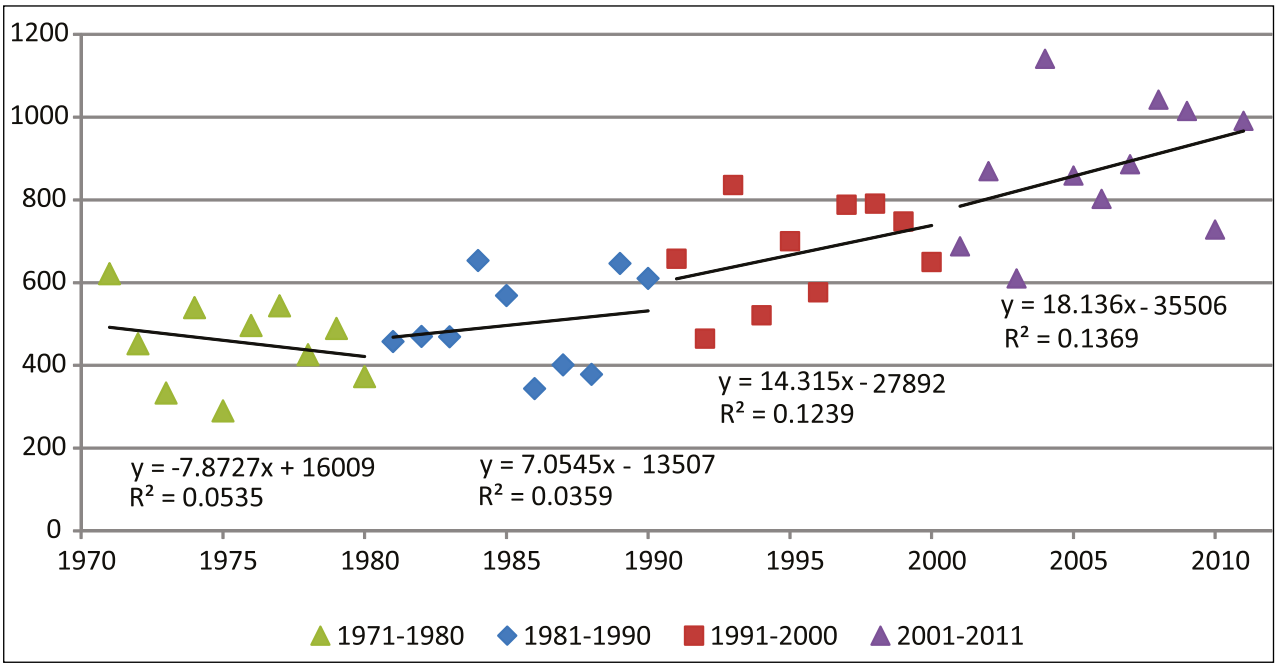

Figure 4. Productivity trends of pearl millet at all-India level, 1970-2011.

Uttar Pradesh stood second in production with a 17.9% share because of an impressive yield of 1,877 kg ha^{-1}. Haryana had a share of 9.6% in production because of a high productivity of 1,908 kg ha^{-1}. Maharashtra registered a 7.8% share in production by recording an average yield of 880 kg ha^{-1}. Gujarat reported the average yield of 1,531 kg ha^{-1} and could contribute to 11% of pearl millet production in the country. These five states together accounted for a 91% share in total country's production.

The area under pearl millet has increased marginally (13%) in the case of Rajasthan between 1976-78 and 2011-15. Except for Rajasthan, all other five states showed declining trends in area under pearl millet crop. With regard to productivity, Haryana state has registered the highest growth (427%) followed by Rajasthan (338%), Madhya Pradesh (298%), Uttar Pradesh (270%), Maharashtra (241%) and Gujarat (176%) during

Table 2. Area, production and productivity of pearl millet in major producing states.

State	1976-1978			1986-88			1996-1998			2008-2010			2011-2015		
	Area (m ha)	Prod (m tons)	Yield (kg ha^{-1})	Area (m ha)	Prod (m tons)	Yield (kg ha^{-1})	Area (m ha)	Prod (m tons)	Yield (kg ha^{-1})	Area (m ha)	Prod (m tons)	Yield (kg ha^{-1})	Area (m ha)	Prod (m tons)	Yield (kg ha^{-1})
Rajasthan	4.07	1.09	272	4.85	1.39	265	4.53	2.20	485	5.27	3.62	684	4.60	4.22	918
Uttar Pradesh	0.97	0.67	694	0.80	0.72	897	0.83	1.08	1293	0.86	1.41	1637	0.91	1.72	1877
Haryana	0.90	0.40	447	0.67	0.47	635	0.58	0.71	1214	0.61	1.06	1718	0.48	0.93	1908
Gujarat	1.46	1.27	872	1.18	0.95	748	1.06	1.36	1273	0.74	0.96	1282	0.69	1.06	1531
Maharashtra	1.70	0.62	365	1.83	0.75	409	1.85	1.48	796	0.97	0.85	864	0.85	0.75	880
Madhya Pradesh	0.17	0.11	630	0.16	0.13	785	0.14	0.15	1076	0.16	0.26	1589	0.19	0.35	1877

Source: Directorate of Economics & Statistics

1976-78 and 2011-15 average period. Maharashtra lost a significant area under pearl millet during the four decades of study period under analysis. However, production and productivity are on an increasing trend due to adoption of improved cultivars/hybrids and improved agronomic practices in the state.

Figure 5 highlights the long-term productivity trend of pearl millet in Maharashtra during 1970-2015. Productivity was at its peak during 2010 and declined afterwards. However, long-term productivity is exhibiting an upward trend with an average growth of 14 kg ha^{-1} per year during the study period. Figure 6 presents four graphs showing pearl millet productivity, one each for the four decades between 1970 and 2010. During the first decade (1970-80), the productivity of pearl millet showed an increase of 24 kg per year. In the next decade (1980-90), the productivity increased by 22 kg per year, but the equation is a weak fit with only 26.5% of the variation in it being explained by the linear trend line. The productivity trend line for the third decade (1990-2000) is a poor fit and it suggested a flattish trend for productivity, hardly suggesting a 2 kg increase in productivity per year. The outbreak of downy mildew might be one of reasons for poor productivity increase between 1990 and 2010. The equation for the last decade (2000-10) is again a good fit and it showed a remarkable increase of 32 kg per year.

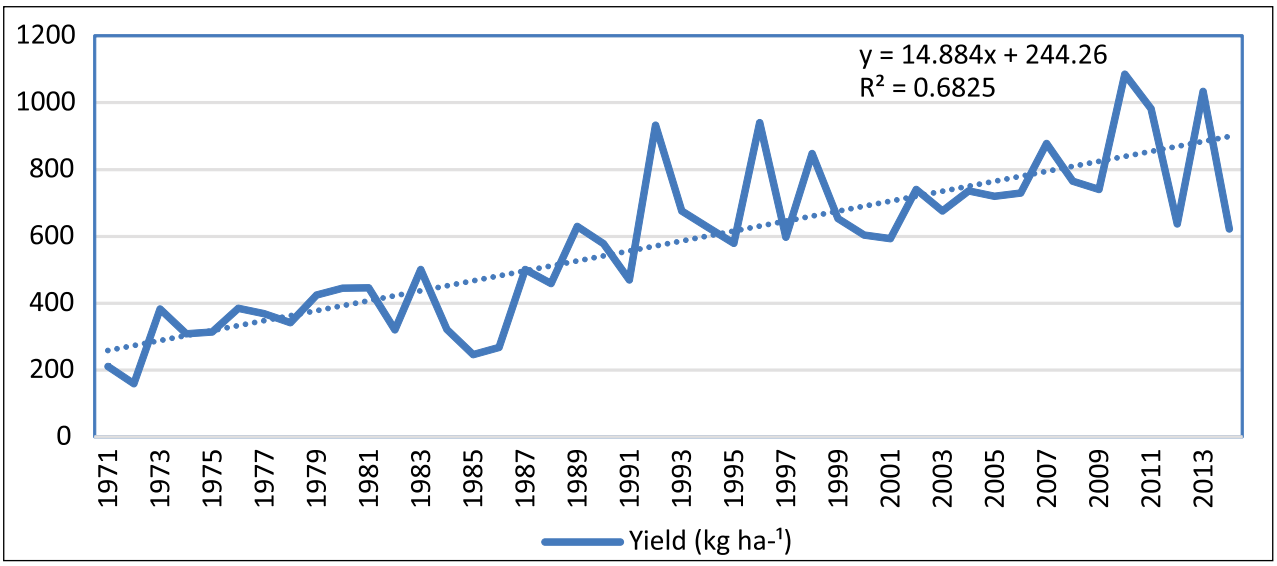

Figure 5. Productivity of pearl millet in Maharashtra, 1971-2015.

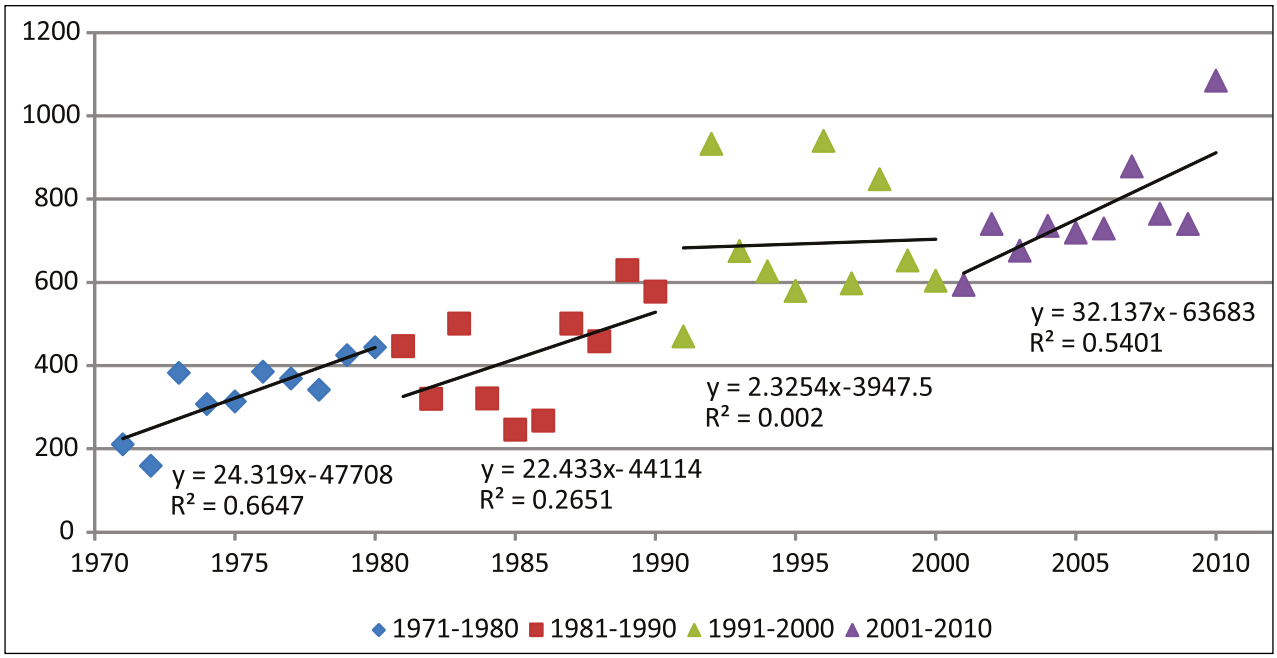

Figure 6. Productivity trends of pearl millet in Maharashtra, 1970-2011.

2.3 Study districts of Maharashtra[1]

Table 3 contains the triennial (2008-10) averages of area, production and productivity of pearl millet in the nine major pearl millet-growing districts of Maharashtra. Nashik and Aurangabad led the other districts in both area and production of pearl millet. But Jalgaon and Aurangabad districts have high levels of productivity of more than 1100 kg per ha.

In all the nine study districts of Maharashtra, there has been heavy erosion in the area under pearl millet between 1990-92 (average) and 2008-10 (average). Pune district lost 80.1% of the area, followed by Jalgaon with nearly 70% reduction. Satara, Sangli, Nashik and Ahmednagar districts lost about 50% of the area under pearl millet. Aurangabad, Dhule and Beed districts also lost between 42% and 25% of the area under pearl millet. Yet, all nine districts achieved gains in pearl millet productivity. The biggest productivity gain of 142.4% was recorded in Aurangabad. Satara recorded a yield gain of 46.5%, followed by Nashik with 43% and Sangli with 31.3% increase. In all the other districts, the yield gain was less than 20% between 1990-92 and 2008-10. These yield gains have moderated the reduction in pearl millet production in all the districts.

3. Historical development of pearl millet improved cultivars

3.1 Pearl millet systems analysis/cropping systems

Pearl millet is generally grown as a rainfed crop in different states of the country during the rainy season. Its spread is restricted to the western part of the country where the length of the growing season is rather short. It is grown as a sole crop as well as a main crop with pigeonpea grown as an intercrop. Rarely, other crops are also intercropped with it. Generally, the land is left fallow during the postrainy season if there are no facilities for irrigation. In Maharashtra and Madhya Pradesh, where soils are deep, postrainy crops such as sorghum, chickpea and safflower are taken after pearl millet. Wherever irrigation facilities exist, crops such as wheat, mustard and potato are grown in the postrainy season after pearl millet. In these areas, pearl millet is also being grown in the summer due to its high productivity within a short period.

Table 3. Area, production and productivity of pearl millet in study districts.

	1990-92			2008-10			% change		
District	Area ('000 ha)	Prod ('000 tons)	Productivity (kg ha^{-1})	Area ('000 ha)	Prod ('000 tons)	Productivity (kg ha^{-1})	Area	Prod	Productivity
Ahmednagar	332.20	226.67	677.67	171.63	131.53	759.67	-48.30	-42.00	12.10
Aurangabad	186.00	117.37	461.13	107.10	117.27	1117.67	-42.40	-0.01	142.40
Beed	174.27	110.80	621.33	129.73	104.75	811.00	-25.60	-5.50	30.50
Dhule	159.70	137.17	852.00	113.00	106.89	971.67	-29.20	-22.10	14.00
Jalgaon	111.70	112.13	992.33	34.00	39.89	1167.33	-69.60	-64.40	17.60
Nashik	359.70	251.50	695.33	180.57	178.94	994.00	-49.80	-28.90	43.00
Pune	205.90	134.17	666.00	43.03	34.62	801.33	-80.10	-74.20	20.30
Sangli	95.40	29.97	315.67	47.17	27.20	414.33	-50.60	-9.20	31.30
Satara	108.43	43.63	405.67	52.30	32.93	594.33	-51.80	-24.50	46.50
Sum of 9 districts	1733.30	1163.41	671.21	878.1	773.6	847.8	-49.34	-33.51	26.31
Total MH	1915.1	1263.9	660.0	978.0	850.3	864.0	-48.93	-32.72	30.90
Share of 9 districts in Maharashtra (%)				89.8	91.0	98.1*			

* % of state average yield

[1] 2008-10 triennium data was considered as the basis for identification of study districts in the state.

3.2 Development of improved cultivars in Maharashtra, 1934-2011

There is a long history of development of pearl millet varieties/hybrids suitable for Maharashtra in the last eight decades (see Table 4). Three varieties – N28-15-1, Kopargaon local and Avsari – were developed and released in 1934. All three varieties were selections from local varieties of pearl millet. The Pearl Millet Research Station, Jamnagar developed and released the first pearl millet hybrid, HB 3, with the help of All India Coordinated Pearl Millet Improvement Project (AICPMIP) in 1968. Another hybrid, BJ 104, was developed in 1972 and it became popular in Maharashtra, Gujarat, Rajasthan and Haryana because of its resistance to downy mildew disease. Indian Agricultural Research Institute (IARI), New Delhi developed and released another hybrid, NHB 5, in 1975. National Agricultural Research Project (NARP), Aurangabad released a variety, AMP 2, in 1981. IARI followed up with another variety, Pusa 163, in 1982. Mahyco, Jalna came out with the first private sector hybrid, MBH 110 in 1982. It followed it up with the marketing of MBH 118 in 1985 and MBH 130 in 1986. Meanwhile, CCS Haryana Agricultural University released its first hybrid, HHB 45; and Mahatma Phule Krishi Vidyapeeth (MPKV), Rahuri developed a variety, Sangam, by selection from the materials received from ICRISAT. Most of these cultivars could not hold up in the market because of their susceptibility to new strains of downy mildew. Punjab Agricultural University developed PHB 10 and PHB 14. While they were tolerant to downy mildew, they possessed sharp awns due to which they did not remain in cultivation for long.

ICRISAT combined multiple sources of resistance for downy mildew and started collaborating with universities and AICPMIP, Pune and released through them three hybrids – MH 179, MH 180 and MH 182 – in 1986. But the most notable contribution from ICRISAT was the development and release of the composite variety, ICTP 8203 in 1988. It was bred from five selected progenies of a landrace from Togo. It is popular in Maharashtra even today, more than 25 years after its release. Mahyco, Jalna developed a number of hybrids, starting with MBH 136 and MBH 149 in 1989, MBH 163 in 1993, Mahyco 204 in 1995, Mahyco 2210 in 2007 and Mahyco 2240 in 2010. Vijaya Seeds, Nath Seeds, Mahendra Seeds, ITC Geneca, Ganga Kaveri Seeds, Devgen Seeds, Nirmal Seeds, ProAgro Seeds (Bayer Bio sciences), New Nandi Seeds, Pioneer Overseas Corporation, Advanta India Seeds, Vibha Seeds, Sagarlaxmi Seeds, Tata Metahelix Seeds, Panchaganga Seeds, Kaveri Seeds, Zuari Seeds, Varun Seeds, Mahodaya Seeds, Rajiv Biogene Seeds etc. have joined the race and brought out a number of hybrid cultivars with desirable characteristics and are competing in the market. Public research organizations such as AICMIP, Pune; NARP, Aurangabad; MPKV, Rahuri; Millet Research Station (MRS), Jamnagar; MPKV, Dhule; NARP, Parbhani; and so on along with seed corporations such as Mahabeej are also developing and releasing or marketing hybrids/varieties to reach different niche areas. Many of them have depended on the germplasm and parental lines from ICRISAT. Till 1999, the arrangement was through informal collaboration; since 2000, many private seed companies have joined the Hybrid Parents Research Consortium (HPRC) of ICRISAT. These hybrids and improved varieties present a wide choice to farmers growing pearl millet. They differ in duration, yield potential, harvest index, disease resistance, grain and fodder quality etc. Many of them are being marketed in Maharashtra.

Table 4. Historical development of pearl millet cultivars suitable to Maharashtra.

Variety/hybrid	Pedigree	Release Year	Released by
N 28-15-1	A selection from local bajra	1934	-
Kopargaon local	A selection from local variety	1934	-
Avsari	A selection from local variety	1934	-
HB 3	Tift 23A XJ 104	1968	AICPMIP MRS, Jamnagar
BJ 104	5141 X J104	1977	IARI, New Delhi
NHB 5	5071A X K559-85	1975	IARI, New Delhi
PHB 10 (HB 6)	PB111A X PIB 155	1975	PAU, Ludhiana
PHB 14 (HB 7)	PB111A X PIB 228	1975	PAU, Ludhiana
AMP 2	-	1981	NARP, Aurangabad
Pusa 763	5141A X D 763	1982	IARI New Delhi
MBH 110	MS 2 X Pollinator NO.2	1982	Mahyco, Jalna
HHB 45	MS 5141A X H90/4	1984	CCS HAU, Hissar
MBH 118	2A X Pollinator No.3	1985	Mahyco, Jalna
Sangam	Developed by selection in F2 and F3 segregated material received from ICRISAT	1986	AICPMIP MPKV, Rahuri
MBH 130	2A X Pollinator No.4	1986	Mahyco, Jalna
MH 179	81A X ICMP 451	1986	ICRISAT Hyderabad
MH 180	834A X ICMP 501	1986	ICRISAT, Hyderabad
MH 182	732A X PNBM 83099	1986	AICPMIP, Pune
ICTP 8203	Bred from 5 selected progenies of a landrace from Togo	1988	ICRISAT, Hyderabad
MBH 136	2 AX PL NO.6	1989	Mahyco, Jalna
MBH 149	4A X PL NO.13	1989	Mahyco, Jalna
VBH 4	VBMS -IA XVBR19	1990	Vijaya Seeds, Jalna
GHB 181	81A X J2002	1990	AICPMIP MRS, Jamnagar
Eknath 301 (NBH 9)	NBMS 13A X NB 37	1991	Nath Seeds, Aurangabad
MLBH 104 (MH 351)	53AXMI 13	1991	Mahindra Seeds, MH
MBH 160	NMS-9 X PI 21	1993	Mahyco, India
ICMH 356	ICMA 88004 x ICMR 356	1993	ICRISAT, Hyderabad
ICMH 312	81A X ICMR 312	1993	ICRISAT, Hyderabad
RHRBH 8609 (Shraddha)	RHRBH 1A X RHRBI 138	1994	AICPMIP MPKV, Rahuri
AHB 251 (Devgiri)	81A X AIB 16	1994	NARP, Aurangabad
PABH 3	PAMS 1A X Zim-1	1995	NARP, Aurangabad
Nandi 30	NMS 3A X NMP 13	1995	New Nandi Seed Corporation, Ahmedabad
Mahyco 204 (MRB 204)	-	1995	Mahyco, Jalna
MLBH 267	3A X 153	1996	Mahindra Seeds Ltd.
RHRBH 8924 (Saburi)	RHRB 5A X RHBI 458	1997	AICPMIP MPKV, Rahuri
PAC 903 (ICI-903)	Private company	1997	ITC Zeneca Ltd., Bangalore

Continued

Table 4. *Continued*

Variety/hybrid	Pedigree	Release Year	Released by
GK 1004	GKPM 1A X GKPM 59R	1997	Ganga Agri Seeds Ltd., Hyderabad
AIMP 92901 (Samrudhi)	Bred by random mating 272 S1 progenies from C5 cycle of bold seeded early composite	1998	AICPMIP RRS NARP Aurangabad, Maharashtra
MLBH 308	-	1998	Devgen Seeds
MLBH 504 (Dev Gen)	36A X MI-67	1998	Devgen Seeds
MLBH 44(MLBH 505, MH 793)	MS40A XMI70	1999	Mahindra Hybrid Seeds Ltd.
Nirmal 9	-	2000	Nirmal Seeds
ProAgro 9330	-	2000	ProAgro Seeds
Nandi 35	NMS 11A X NMP 42	2001	New Nandi, Ahmedabad
Pioneer 86 M 32	-	2002	Pioneer Hybrid Seeds
Nirmal 40	-	2002	Nirmal Seeds
PPC 6 (Parbhani Sampada)		2005	AICPMIP RRS NARP Parbhani
Sagar 205		2005	Sagarlaxmi (MH)
B -2301(B -2301)	B 0009A X B 5103R	2007	Zuari Seeds Ltd, Bangalore
Kaveri Super Boss	-	2007	Kaveri Seeds
PB 727 (ProAgro 9555)	PSP 51 X PP 38	2008	Bayer Bio Science
MH 1351 (Sagar Urmi)	pedigree not available (private company)	2008	Sagarlaxmi (MH)
MH 1352 (Biogene 66)	pedigree not available (private company)	2008	Rajiv Biogene (MH)
GK 1051	PM 678A-II x PM 1081 R-I	2008	Ganga Kaveri, Hyderabad
Pioneer 86 M 33	-	2009	Pioneer Hybrid Seeds
Dhaanya 7872	-	2009	TATA Metahelix
RHRBH 9808	RHRB 13A x RHRBI 1314	2010	AICPMIP, MPKV, Dhule
Mahyco 2240 (MRB 2240)	-	2010	Mahyco, Jalna
VBBH 3040	VBBA 310089 X VBBR330585	2011	Vibha Seeds, AP
PAC 909	110057X130453	2011	Advanta India Ltd.
86 M 53	M096F x M 119R	2011	Pioneer Overseas Corp.
86 M 64 (MSH 203)	M096F x M 117R	2011	Pioneer Overseas Corp.
Tilak (DB 2013)	-	2011	Dev Gen Seeds
M 1003 (Manik)	-	2013	Mahabeej, MH
GK 1044	-	-	Ganga Kaveri Seeds
Mahyco 163 (MBH 163)	-	-	Mahyco, Jalna
Panchaganga 510	-	-	Panchaganga Seeds
Varun 666	-	-	Varun Seeds
MDBH 318	-	-	Mahodaya Seeds
Mahyco 2210 (MRB 2210)	-	-	Mahyco, Jalna

Source: TRIVSA database, 2012

3.3 Policy bias against coarse grains and pearl millet

In general, coarse grains were the staple grains produced and consumed in the rainfed areas of the country. After independence, 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 the regions to build more and more of these projects.

The lands receiving water from irrigation projects appreciated in value, reached higher productivity levels and received 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 like pearl millet are grown, never received the benefits of any compensating public investments and remained low productive areas (Rao 2006 and see Box 1). Once irrigation facilities were developed, cropping patterns changed from coarse cereals like pearl millet to fine cereals such as rice, wheat and so on. In case of irrigated areas, marketable surplus were produced in crops such as 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 the PDS, the rice and wheat procured were distributed at subsidized prices. It became possible to access fine cereals at much lower prices than the coarse grains like pearl millet via the PDS. The PDS has 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 MSP announced for pearl millet was about the same as that announced for coarse variety of paddy; it remained so up to 1982-83. However, the difference between the MSP of coarse variety of paddy and pearl millet kept on widening over the years. They were brought back to the same level only in 2012-13. For nearly 30 years, farmers growing pearl millet and other coarse grains were discriminated against by the MSP policy (see Figure 7). This was only one part of the story.

Coarse grains such as pearl millet were procured rarely, if at all, by the FCI even when market prices fell below the MSP, whereas procurement of rice and wheat was a routine operation in the surplus states, both when their market prices were above the MSP and when they fell below the MSP. Some reasons were put forward for non-procurement of coarse grains like pearl millet. One reason was that there is no consistent marketable surplus in case of pearl millet, as its production is subject to the vagaries of the monsoon. Another reason was that coarse grains like pearl millet are difficult to store and deteriorate in quality much faster than rice and wheat. This disadvantage could have been overcome by research on storage and innovative processing. They were not included in the PDS till last year, when NFSA was passed. Theoretically, a consumer can demand coarse grains like pearl millet at ₹ 1 kg^{-1} but it is not known whether

Box 1: A study conducted by KPC Rao (2006) in Andhra Pradesh estimated the levels of input subsidies accessible to rainfed and irrigated farmers between 1994-95 and 2002-03. Overall, the weighted average subsidy received in 1994-95 was Rs. 1940/ha and it went up to Rs. 3578/ha by 2002-03. It indicated a remarkable increase of 84% over a span 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 rainfed hectare received only Rs. 356 as input subsidy. The percentage increase in subsidy per hectare was 99% in case of irrigated agriculture, while it was only 9% in case of rainfed agriculture. The input subsidies received by an irrigated hectare were 13 times that of a rainfed hectare in 1994-95. This ratio has grown 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 accounted for rice alone in the state. Cotton and groundnut followed it distantly with their shares at 5% and 4% respectively. Dryland crops such as sorghum, pearl millet and finger millet together accounted for less than 1% of the total subsidies.

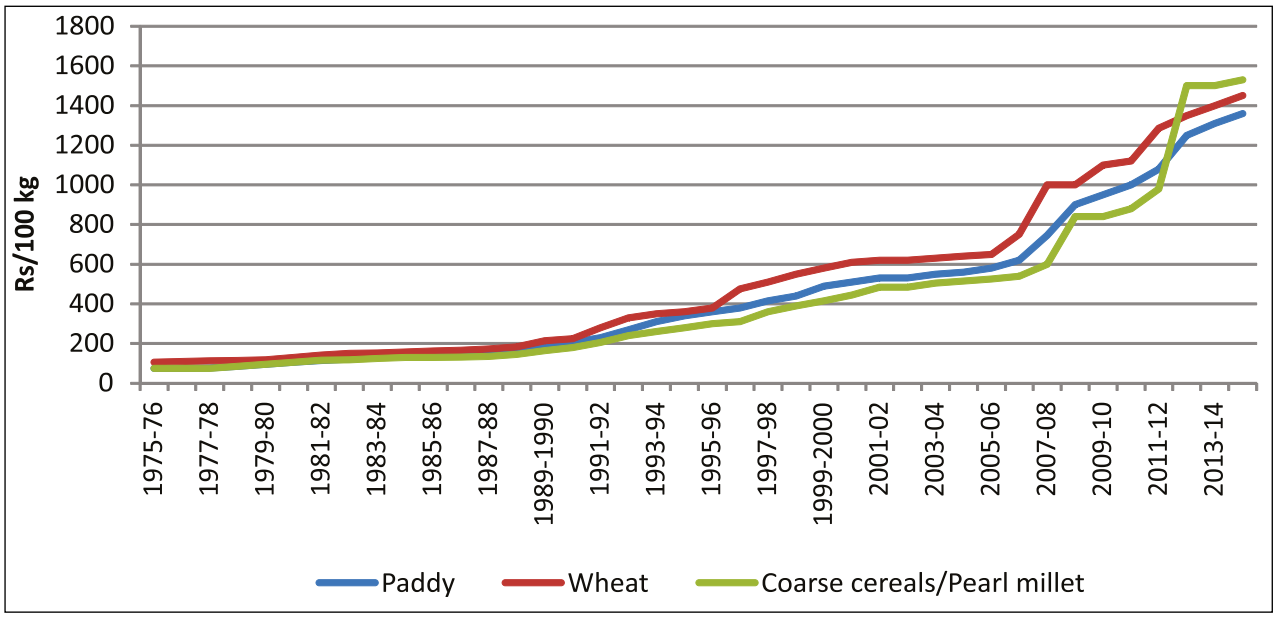

Figure 7. Minimum support prices of fine and coarse cereals in India.
Source: Ministry of Agriculture and Cooperation, 2016

the government will be able to fulfil this promise as procurement operations are yet to begin in the case of coarse cereals such as pearl millet and 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 8). Paddy price also largely ruled above the prices of sorghum and pearl millet, except for one or two exceptional years.

These policy biases of governments inhibited growth in pearl millet production. In contrast, the production of rice and wheat has increased several folds as they were able to ride on the crutches of capital and production subsidies as well as consumption subsidies given to the poor in the PDS. If the capital costs of irrigation projects were fully recovered from the beneficiaries, the profit surplus earned in case of paddy and wheat would have been much lower. In the same way, if rainfed areas also received compensating production subsidies at the same level as given to irrigated areas and crops, the reduction in areas under coarse grains would not have been as dramatic as were witnessed during the last four decades. Similarly, if coarse cereals were treated on par with rice and wheat in the PDS, and if they were not discriminated against in the fixation of MSP, they would have retained substantial areas under production. Had the

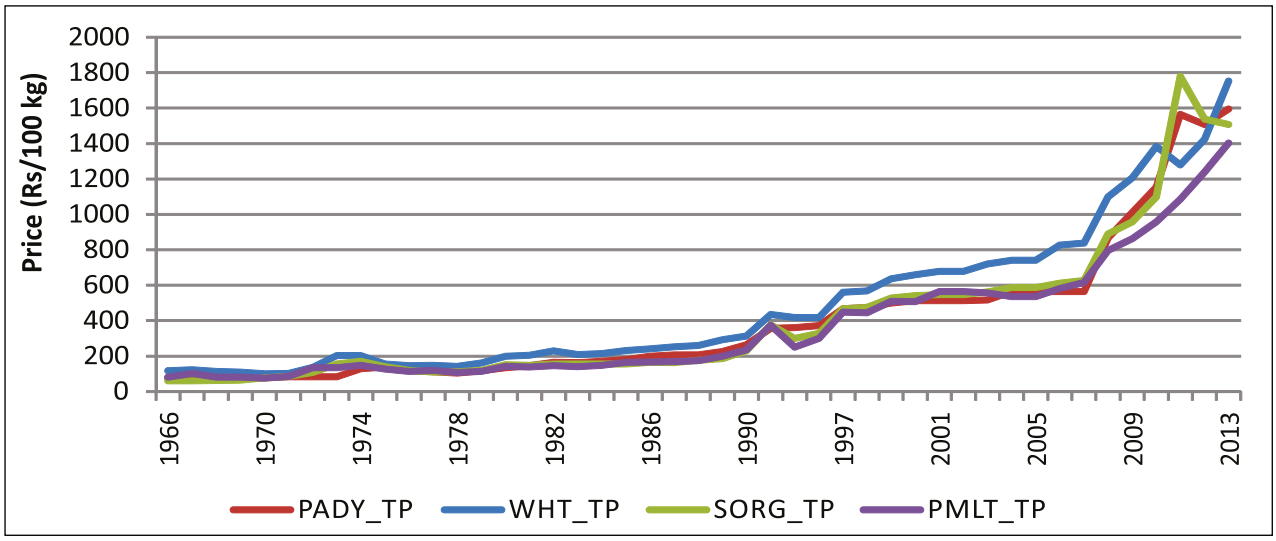

Figure 8. Farm harvest prices among cereals in Maharashtra.
Source: Ministry of Agriculture and Cooperation, 2016

coarse cereals received the same kind of procurement support as rice and wheat, pearl millet would not have lost its area as it happened. All these policies have done much more harm to pearl millet farmers than natural calamities like droughts and excess rain. The hard work of pearl millet researchers and farmers would be recognized much more if there was a similar emphasis in public policies. Normally, policy is expected to come to the rescue of the disadvantaged. In this case, policies had the opposite effect. They have aided the replacement of coarse cereals by fine cereals. Incongruously, it also meant robbing poor farmers of the rainfed areas and fattening the rich in the well-endowed areas.

3.4 Pearl millet supply and demand in India

Estimates of production of pearl millet are projected for the period from 2010 to 2050 using IFPRI-IMPACT[2] model. While the area under pearl millet is projected to go down from 10.5 to 8.25 million ha by 2050, its production is projected to increase beyond 14 million tons by 2050 (see Figure 9). It implies that the productivity will go up to 1721 kg ha^{-1} by 2050. Alternate uses such as feed and other products are also projected to increase by 2050 (Figure 10). Based on IFPRI-IMPACT model projections, the demand for pearl millet grain in 2010 was estimated at nearly 9.8 million tons. Food demand alone accounted for 9 million tons, leaving the remaining 0.8 million tons for feed and other uses, such as industrial purposes (Figure 10 and also Nedumaran et al. 2013). In 2050, the total demand is expected to reach close to 11 million tons and the food demand is expected to reach 9.5 million tons. The demand for feed and other uses is expected to be 1.5 million tons. Their share in total demand is expected to double from 8% in 2010 to 16% by 2050. It shows that the composition of total demand for pearl millet is changing in favor of feed and other uses, albeit slowly. The component of feed in particular is increasing in relative proportion. The enhanced awareness about nutritious cereals also creating the demand for grain consumption in the country during recent times. The projected climate change impacts by IPCC in India also favors the expansion of coarse cereals due to their high tolerance to increased temperature and water scarcity.

Reddy et al. (2013) studied the utilization pattern, demand and supply of pearl millet grain and fodder in Western India (comprising Gujarat, Rajasthan and Haryana) for the years 2011 and 2020 based on historical growth rates estimated from 1996-2009. The projected demand for pearl millet grain including food, feed and other uses will increase from 6.69 million tons to 8.47 million tons between 2011 and 2020. In Western India, 46% of production of pearl millet grain went towards human consumption, 37.5% for cattle feed, 7.7% for poultry feed, 8.8% for alcohol production and only a small fraction (0.4%), was used for seed purpose in 2011. By 2020, the share of cattle feed will increase to 38.6%, poultry feed to 9.4%, and alcohol industry and other non-food uses will go up to 11.7%, while food uses will decrease to

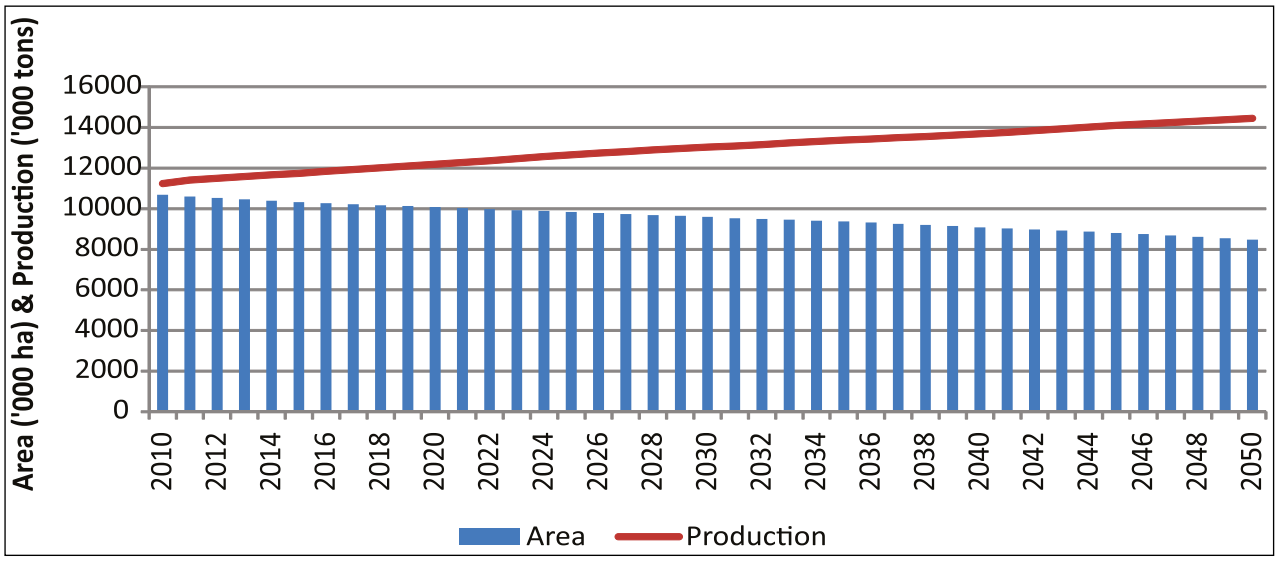

Figure 9. Millet area and production in India, 2010-2050.

2. See more details in Nedumaran et al. 2013

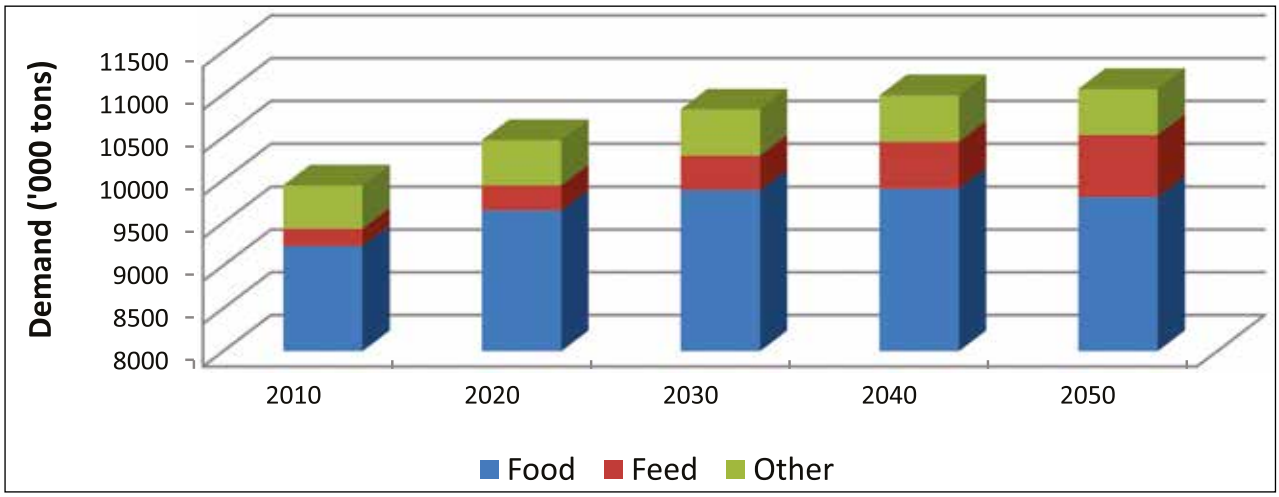

Figure 10. Millet food, feed and other use demand in India, 2010-2050.
Source: IFPRI-IMPACT model projections

40%. Even though currently there is a shortage of pearl millet grain production in Western India, which is indicated by higher prices, by 2020 the region will become surplus to the extent of 5% if it maintains the current production growth trend of 4.22% per annum.

3.5 Per capita consumption

Millets are a group of small-seeded annual grasses grown mainly in Asia and Africa and account for less than 1% of global cereal production and 3% of coarse cereal production. Asian countries are the second most important block of millet producers, accounting for 38% of the global area and 42% of the global production. Yields are somewhat higher in Asia compared to Africa, as improved/hybrid seeds are widely used, though the total production in these countries has been falling as farmers are shifting to other, more remunerative crops. They are sparsely traded with less than 1% of total millet production being exported. However, they are significant contributors to the food security of the people living in Africa and Asia. Pearl millet is the most important millet both in terms of area and production. It accounts for 75% of the total millet area in India. Millets are also used as bird feed, but this use is largely restricted to the developed countries. However, the utilization pattern is changing even in developing countries where its use in alcohol manufacture and as livestock and poultry feed is growing. Millet fodder is an important feed resource in the dryland systems of Africa and Asia, particularly in the post-monsoon seasons when other feed resources are not available.

Pearl millet consumption trends in India[3]

The consumption trends of pearl millet in India in the past two decades, both in rural and urban areas depict a sharp decline in consumption (see Figure 11). However, the trends in both rural and urban areas have plateaued since the late 1990s at the current lower levels. There is a significant difference in the levels of pearl millet consumption along the rural and urban divide. Pearl millet consumption in urban India was always low because of the low shelf life of processed flour which entails processing the grain before using it.

Pearl millet is consumed predominantly in the western and central states of India. However, it is consumed as a staple mainly in Gujarat and Rajasthan. Haryana, which was a significant consumer of pearl millet in the 1970s, saw consumption decreasing by over 85% in both urban and rural areas. Across income classes, pearl millet is consumed mainly by the low- and middle-income groups. The high-income group accounts for less than 10% of total pearl millet consumed as food in rural areas and less than 5% in urban areas. About 46% of pearl millet in urban India is consumed by low-income consumers (see Table 5). Thus, pearl

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

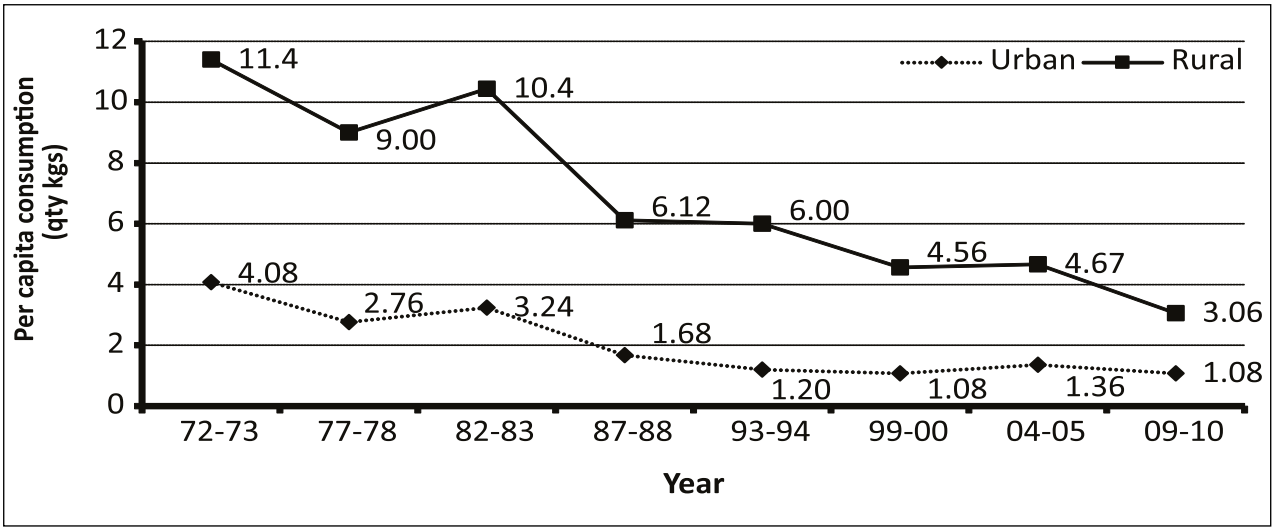

Figure 11. Annual per capita consumption of pearl millet in India.
Source: Compiled from Level and Pattern of Consumer Expenditure, NSSO 62nd Round, 2009-10

millet continues to be an important staple for the poor despite an overall decline in its consumption. It is particularly true in the western part of the country. About 13% of pearl millet production is used for feed and, in some areas, it is used by the alcoholic beverage industry.

Fodder

Pearl millet straw is an important feed resource, particularly in India and parts of sub-Saharan Africa. In India, particularly in the arid zone, pearl millet straw is stored and used throughout the year, particularly in the summer months when other feed resources are scarce. There is also a growing market for pearl millet straw in urban areas close to the growing centers to meet the increasing demand from urban and peri-urban dairies. Chopped pearl millet straw is commonly traded in urban markets due to its transportability and ease of consumption by animals. Pearl millet dry stover is often traded from Haryana, Punjab and UP to Rajasthan whenever pearl millet stover is in short supply due to drought. Pearl millet is also exclusively grown as a fodder crop under irrigation in Punjab, Haryana and Western Uttar Pradesh.

Table 5. Annual consumption of pearl millet by income class, 2009-10.

	Consumption		Per capita consumption	Population
Expenditure category	('000 t)	(%)	(kg yr^{-1})	(%)
Rural average consumption by expenditure category				
Low (Less than Rs. 765 (USD 14.98) per month)	826.6	35.6	2.72	50
Medium (Rs. 765–1477 (USD 14.98–28.93) per month)	1,221.2	52.6	4.01	40
High (Greater than Rs. 1477 (USD 28.93) per month)	274.0	11.8	1.80	10
Urban average consumption by expenditure category				
Low (Less than Rs. 1307 (USD 25.60) per month)	145.9	49.8	1.29	50
Medium (Rs. 1307–3166 (USD 25.60–62.02) per month)	119.2	40.6	1.06	40
High (Greater than Rs. 3166 (USD 62.02) per month)	28.1	9.6	0.50	10

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

3.6 Livestock population census in Maharashtra

The livestock census data for Maharashtra as well as for India illustrate that the livestock numbers increased till 1997 but declined by 2003 (Table 6). The number of cattle reared for both draft and milk purpose increased in Maharashtra between 1992 and 1997, but decreased during the next six-year period. 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 decreases, the requirement for fodder also decreases, which thus becomes a dampener on the acreages of sorghum and pearl millet, grown by farmers for both grain and fodder.

Table 6. Livestock population in Maharashtra and India.

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

Source: Livestock census, GOI, 2016

3.7 Long-term supply and demand elasticity of pearl millet

The literature survey did not find estimates appropriate to pearl millet, 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, decreased to 0.424 for the moderately poor, and further decreased to 0.312 for the non-poor (lower-income) consumers. In the case of non-poor (higher-income) consumers, 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 FCDS (Food Characteristic Demand System) 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. In the 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 QAIDS 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 (higher-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 also tend 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, using relative price as their explanatory variable. The right measures could be obtained by regressing acreage against own price and not against relative price. Due to the paucity of literature with respect to demand-and-supply elasticity of pearl millet, some realistic assumptions have to be made for making the welfare estimates due to technical change.

4. Sampling framework and methodology

Maharashtra stands fourth in pearl millet production in India, with an 11% share in both area and production. The district-wise distribution of pearl millet crop between 2006 and 2011 is depicted in Figure 12. In general, as a crop, pearl millet is most preferred in harsh climatic regions where rainfall is both scarce and low. Mostly, farmers prefer to grow pearl millet during *kharif* (rainy) season. In a few locations, farmers are cultivating it during summer season with irrigation. Overall, private seed companies have clear domination over the public sector in the seed market. Nearly 80% to 90% of the total seed demand in the state is met by the private sector. The new, improved hybrids have penetrated well into the market than the Open Pollinated Varieties (OPVs). In general, an improved hybrid has nearly 30%–40% yield advantage over any of the OPVs. The adoption of improved cultivars is at its peak in the state and it is worthwhile to conduct a comprehensive study to understand the whole process of adoption and its impact on farm productivity.

Figure 12 shows that Nashik, Ahmednagar and Beed are the districts where pearl millet cultivation is concentrated. Aurangabad and Dhule have medium concentration, while Jalgaon, Jalna, Pune, Satara and Sangli also had considerable areas under the crop during the 2006-11 quinquennial period.

4.1 Sampling design

As discussed and explained in the previous sections, an exclusive state-level representative survey was conducted for pearl millet crop for better understanding the adoption levels as well as the research process. Based on the recent *tehsil*-level secondary data, the distribution of pearl millet is summarized in Table 7. However, the corresponding *tehsil*-level distribution and extent of coverage is presented in Table 8.

Based on 2006-2011 secondary data, the pearl millet crop is spread over 208 *tehsils* in the state of Maharashtra (see Table 7). If we consider only the *tehsils* with more than 1000 ha, there are 101 such *tehsils* and they together account for 98% of the area under the crop in the state. Eighty-one *tehsils* have more than 3000 ha under pearl millet and they together cover 94.9% of the area. There are 66 *tehsils*,

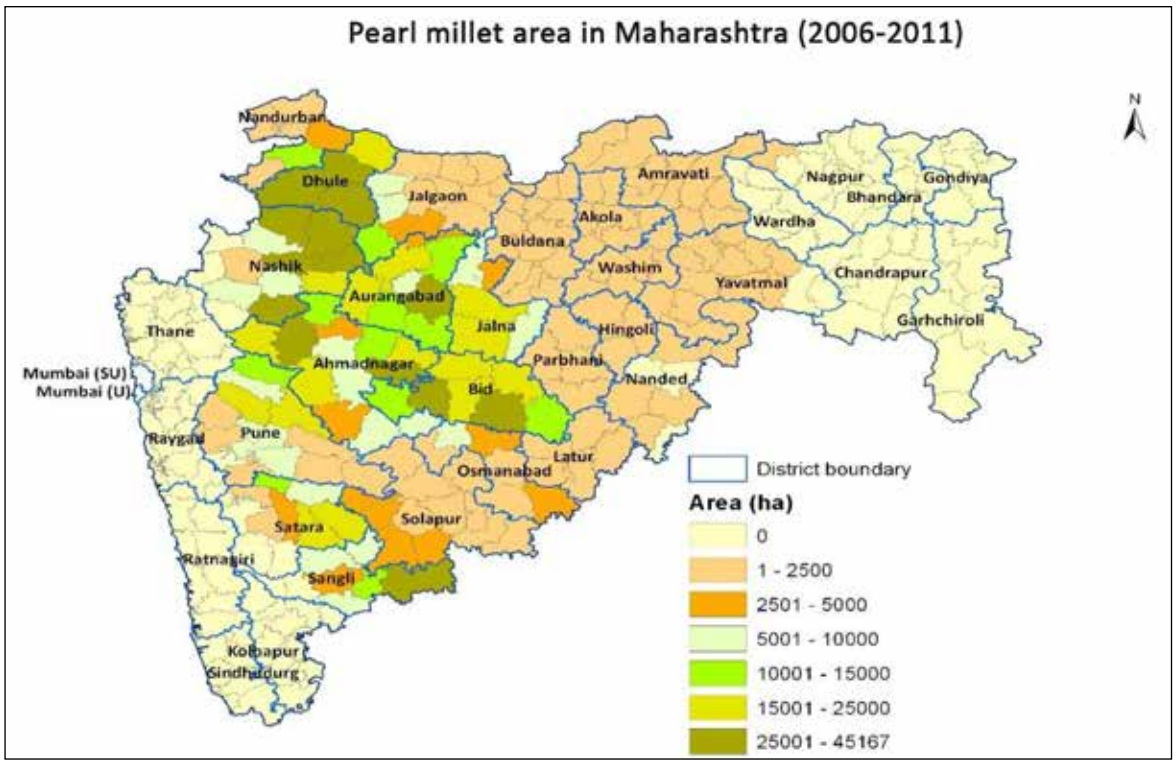

Figure 12. Distribution of pearl millet crop in Maharashtra state, 2006-11.
Source: Directorate of Economics and Statistics, Pune, 2012

each with more than 5000 ha under the crop, which together account for 89.9% of the cropped area in the state. Among the three alternative options, the 5000 ha-per-*tehsil* scenario is selected as a reasonable cut-off point to achieve the representative coverage of almost 90% cropped area in the state. About 66 *tehsils* from 11 districts fall under this category. With binding limitations of time and cost, the project selected only 20 *tehsils* through a sample design using probability proportional to cropped area approach. Based on the randomization procedure, the sampling strategy was designed for pearl millet in Maharashtra (see details in Appendix 2). Finally, the sample for the study covered 360 households from 60 villages and 20 *tehsils* in nine districts of Maharashtra state (see Table 9). The selected sample villages and districts across Maharashtra are also depicted in Figure 13.

Table 7. District-wise distribution of pearl millet area, 2006-2011.

District	No. of mandal (area > 0 ha of pearl millet)	Total area (ha)	No. of mandal (area > 1000 ha of pearl millet)	Total area (ha)	No. of mandal (area > 3000 ha of pearl millet)	Total area (ha)	No. of mandal (area > 5000 ha of pearl millet)	Total area (ha)
Ahmednagar	14	198301	14	198301	14	198301	11	186816
Akola	7	816	-	-	-	-	-	-
Amravati	14	236	-	-	-	-	-	-
Aurangabad	9	111100	9	111100	9	111100	8	107447
Beed	11	147085	11	147085	11	147085	10	142977
Buldhana	13	3501	-	-	-	-	-	-
Dhule	4	114709	4	114709	4	114709	4	114709
Hingoli	5	235	-	-	-	-	-	-
Jalgaon	15	40218	7	37901	5	35304	3	27659
Jalna	8	47310	8	47310	7	44493	5	36775
Latur	10	4948	2	2098	-	-	-	-
Nagpur	1	1	-	-	-	-	-	-
Nanded	6	160	-	-	-	-	-	-
Nandurbar	6	14937	2	13872	1	10956	1	10956
Nashik	11	203052	9	202769	9	202769	9	202769
Parbhani	9	6638	2	2716	-	-	-	-
Pune	12	74117	9	73285	6	68326	6	68326
Sangli	8	64201	7	63945	6	62661	5	58965
Satara	7	65127	5	64584	5	64584	4	61516
Solapur	11	16752	4	13550	2	9494	-	-
Osmanabad	8	18383	8	18383	2	6612	-	-
Washim	6	770	-	-	-	-	-	-
Yavatmal	13	1165	-	-	-	-	-	-
Grand Total	208	1133764	101	1111609	81	1076395	66	1018916

Table 8. *Tehsil*-wise distribution of pearl millet in Maharashtra.

Tehsil-level pearl millet area (ha) cut-off	No. of *tehsils* where pearl millet is grown	% coverage in the state
> 0 ha	208	100.0
> 1000 ha	101	98.0
> 3000 ha	81	94.9
> 5000 ha	66	89.9

Source: Directorate of Economics and Statistics, Pune, 2012

Table 9. Selection of mandal for the study.

S. No.	District	Mandal	S. No.	District	Mandal
1	Ahmednagar	Sangamner	11	Dhule	Sindkheda
2	Ahmednagar	Pathardi	12	Jalgaon	Parola
3	Ahmednagar	Shevgaon	13	Nashik	Malegaon
4	Ahmednagar	Rahuri	14	Nashik	Sinnar
5	Aurangabad	Aurangabad	15	Nashik	Baglan (Satana)
6	Aurangabad	Gangapur	16	Nashik	Chandwad
7	Beed	Patoda	17	Pune	Shirur
8	Beed	Majalgaon	18	Pune	Purandhar
9	Beed	Parali	19	Sangli	Kavathe-Mahankal
10	Dhule	Sakri	20	Satara	Man

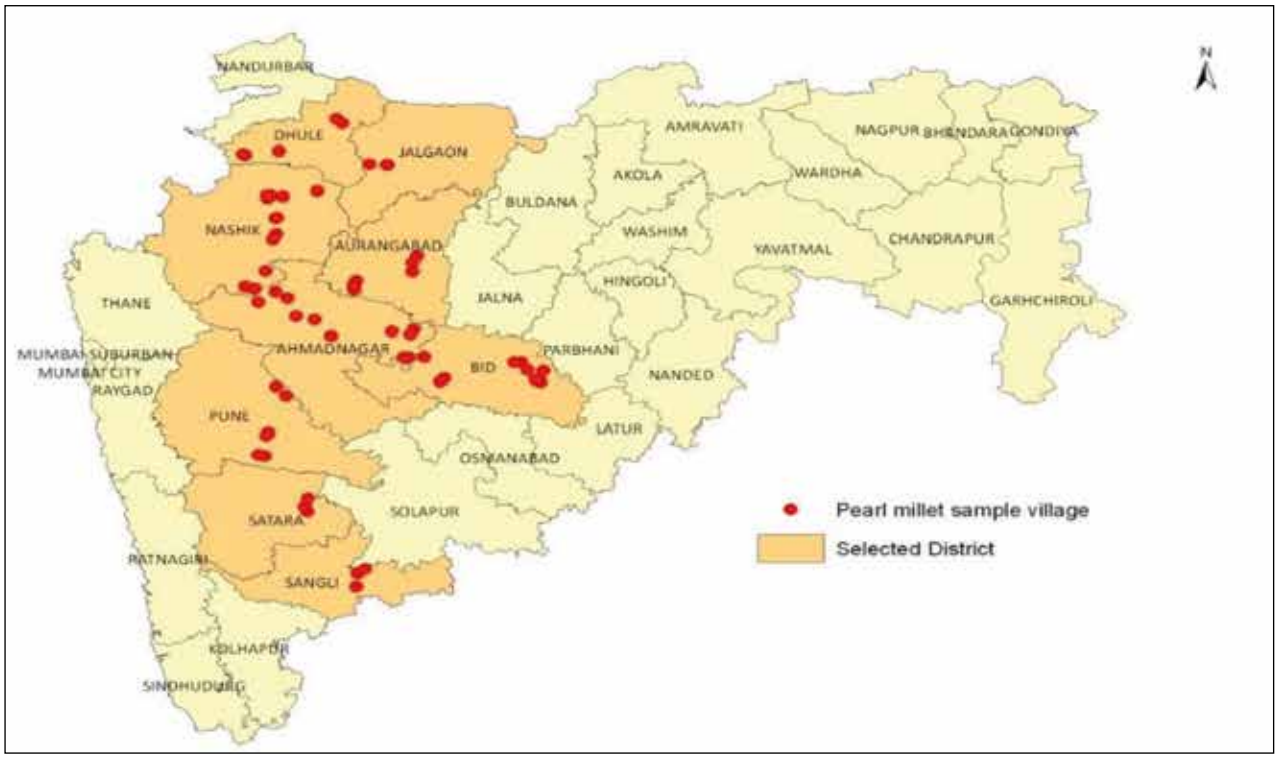

Figure 13. Selection of villages for primary survey in Maharashtra.

4.2 Sampling efficiency

The details of sampling procedure used for selection of the study *tehsils* are summarized in Appendix 2. The pearl millet cropped area in the state was distributed across nearly 23 districts during 2006-2011. Nearly 86% of the state's pearl millet area (2006-2011) was distributed in the nine sample districts (see Figure 12). The rest of the cropped area was sparsely distributed in around 14 districts of the state. Most of the pearl millet-concentrated *tehsils* (>5000 ha/*tehsil*) are located in WMH region followed by MTW. Based on the probability proportion to area concentration and randomization procedures, 20 *tehsil*s were identified for coverage in the primary household survey. Among the nine sample districts identified, seven belong to WMH and the rest two in the MTW region. So, the study sampling framework is representative of crop distribution as well as pearl millet growers in the state.

4.3 Methodology for quantification of *ex-post* research benefits

Bantilan et al. (2013) emphasize 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 14 is the simplified schematic representation of the research process used. It illustrates the sub-components of the complex interactions which ultimately lead to impacts and then changes the welfare of the community. It highlights the importance of understanding the range of production environments (research domains) that are applicable to pearl millet and especially the one(s) which generated the research focus on improved cultivars.

It notes the importance of understanding the strength of 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 pearl millet producers and consumers; more importantly, it is worth noting how many groups are ultimately influenced by the initial pearl millet market changes.

The welfare impacts consistent with the above *ex-post* framework can be estimated using formulas adapted from Bantilan et al. (2013; pp. 34-36). This set of formulas includes all of the parameters from Figure 14. Some are only important for *ex-ante* impact assessment analysis. They have been left in the

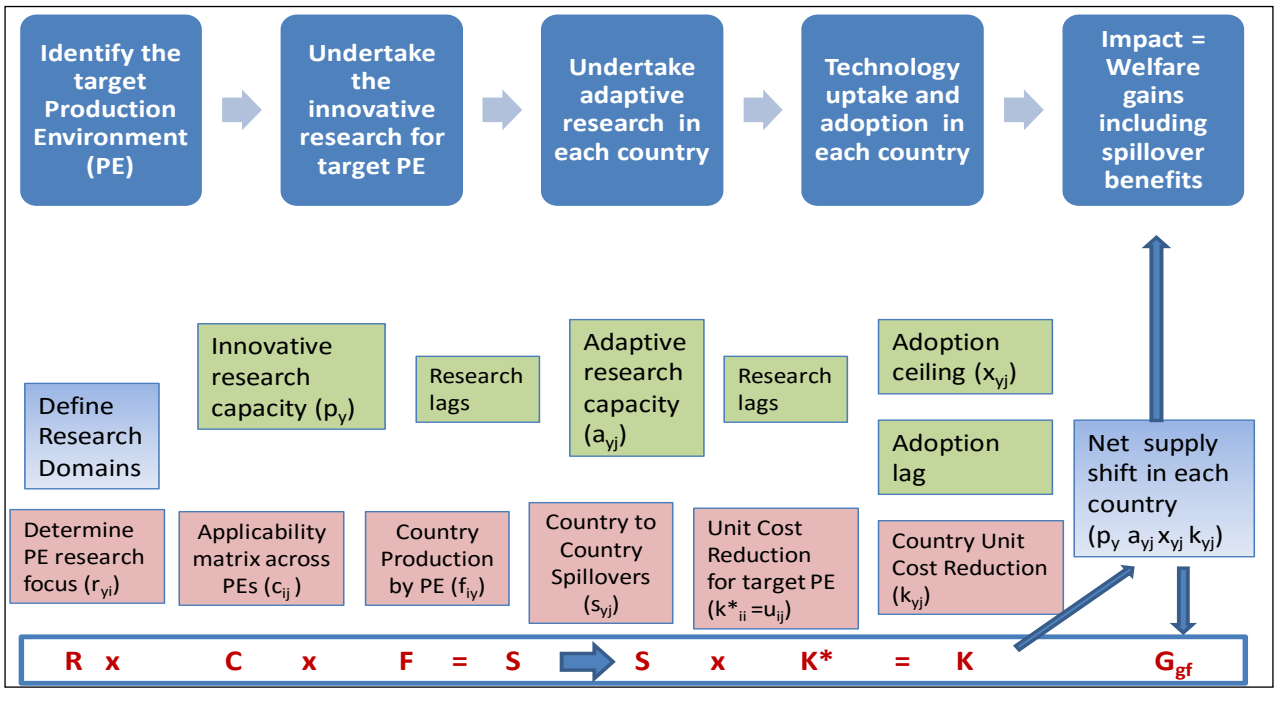

Figure 14. Research process and parameters required for welfare impact estimation.
Source: Bantilan et al. 2013

formulas for the *ex-post* analysis and are therefore 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 careful consideration. In some cases, 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 pearl millet improved cultivars 'g' (f = 1 ... n) are given as:

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

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

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

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

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

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

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

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

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

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

Where:

p_{yt} is the probability of success of the innovative pearl millet research undertaken by ICRISAT and its NARS partners 'y' in year 't' ($0 \leq p_{yt} \leq 1$). As 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 pearl millet 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 and will change each year. Underneath specifying this parameter is the complex set of understanding of the various research and adoption lags plus an assessment of when adoption reaches ceiling level.

4. See more details at Bantilan et al. 2013.

k_{yft} is the unit cost reduction (UCR) resulting from adoption of the pearl millet 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 pearl millets 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 pearl millet 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 district, state, country or region producing and consuming pearl millets in Maharashtra state.

Figure 14 includes a complex schematic for identification and modelling requirement of research domains, research applicability and spillovers between all producers and consumers of pearl millet. This is achieved through adjusting the UCR, k, parameter. This was not formally used to calculate the UCR for each farmer grouping, district, state, country and region 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 UCR 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 short 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 Appendix 4 in the report.

The important sets of data are:

Parameter	Assumptions/source of information*
Pearl millet 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 Appendix 4.

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 has partial equilibrium, so all the economic interactions are only the first round impacts on the Maharashtra pearl millet markets. General equilibrium considerations tell us that the second and subsequent round of interactions will dissipate these first round welfare distributions much more widely throughout the local and then world economies. The efficiencies, and even the 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 judgements about data selection and interpretation, then the total welfare changes will be 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 those hybrids and cultivars of pearl millet on which the survey has to be focused.

5.1 Field reconnaissance survey

During June, 2013, the economists, along with the consultant (a plant breeder), visited all the 20 selected *tehsils* in the nine districts that are important for pearl millet in the state. They visited quite a few seed

shops marketing improved pearl millet seeds in these *tehsil*s. Through this reconnaissance survey, the survey team was able to assess the popularity of different pearl millet hybrids/OPVs, their approximate shares in the seed sales, and the distinguishing characteristics that made them popular with farmers. While some cultivars were preferred in some *tehsils*, the survey team were able to make a list of 10 to 20 popular hybrids/OPVs in the state on which the survey could focus. The survey team also collected the names of villages where pearl millet cultivation is mostly concentrated in the *tehsil*. To cross check, the survey team also met the Taluka Agricultural Officers (TAOs) and discussed about the ruling cultivars dominant in the pearl millet area mostly during the rainy season. The sowing reports available with the agricultural officers were quite handy for verifying and finalizing the villages that should be included in the sample. Pearl millet cropped area has been declining marginally throughout the state in recent years (after 2006). Maize and cotton are making inroads into 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 decided to classify the hybrids/varieties popular with the farmers that were first marketed before 2000 and those developed and first marketed after 2000. Some of the early maturing varieties are suitable for light soils and low rainfall areas. Some of the medium-duration hybrids/varieties developed before 2000 are still popular with the farmers in some areas. Of course, the medium duration varieties developed and marketed after 2000 are quite 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 the economists and biophysical scientists, the team finalized the survey instruments.

5.3 Training program for survey team

A training program was conducted for the survey team at MPKV, Rahuri. The investigators were agricultural graduates and post-graduates with some exposure to the surveys. The supervisor has more than three decades of experience in conducting surveys. The economists and supervisor conducted the training for three days, with pearl millet breeders chipping in as guest faculty. While visiting shops during the reconnaissance survey, the survey team took photographs of the seed packets of different hybrids/OPVs and companies, which were shown to the investigators so that they get an idea of the characteristics of the ruling hybrids (see Appendix 3). The familiarization of investigators with the ruling hybrids was expected to develop confidence while interacting with the farmers as well as for proper identification of 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 pearl millet farmers could remember easily the attractive bag of seeds rather than name of the cultivar.

5.4 Household data collection

After the training, the next two days were spent on pre-testing the questionnaire. It was to ensure that the investigators were able to understand and put across questions to the farmers with ease. The survey group carried out the data collection work over 40 days during August-September 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. Data were collected from a total of 360 sample farmers. Half of them were also administered the input-output (costs-returns) module. The supervisor was backing up the investigators by correcting the filled-in questionnaires and by pointing out the 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 outliers in data.

6. Results and discussion

Details about pearl millet farmers household characteristics, landholdings, average cropping patterns and cropping systems, household assets, consumption expenditures, costs and returns of different crop enterprises, competitiveness of pearl millet vis-a-vis other crops, adoption of various pearl millet improved cultivars, impacts of pearl millet improved technology at farm level, aggregated technology welfare benefits at state level, household networks and perceptions about household sustainability etc, are summarized and discussed in this section.

6.1 Characteristics of sample households

The characteristics of pearl millet sample households across two regions of Maharashtra are analyzed and furnished in the below sub-headings:

6.1.1 Socio-economic features of sample

The sample households are typically from the middle aged group, with 25 years of experience in farming (Table 10). Their experience with pearl millet is as old as their experience of farming. Except for a lone household in WMH, all the remaining 359 households are male headed. The average age of respondents was slightly higher (49 years) in MTW than in WMH (47 years) region. The average years of education of the household head was about 7.5 years in both regions. The average family size was marginally higher in MTW (5.47) than in WMH (5.08). The size of family labor force as well as their participation in the labor market was also higher in MTW than in WMH. The participation rates of male members is higher than of females, both at own farming and outside labor market.

6.1.2 Occupational structure of households

The main occupation was farming for all the households in both the regions, with the exception of one farmer in MTW who considered livestock rearing as his main occupation (Table 11). Non-farm labor and livestock rearing were the secondary occupations of the sample farmers in the two regions. Only a few farmers relied on salary employment and rental income for supplementary income.

Table 10. Socio-economic features of sample households.

Item/Districts	Unit	MTW (N=90)	WMH (N=270)	Pooled (N=360)
Years of farming	Years	24.93	25.38	25.27
Years of pearl millet farming	Years	24.61	24.82	24.77
Household head (no.)	Male	90	269	359
	Female	0	1	1
Average age of household head	Years	49.38	47.04	47.63
Education (years completed)	Years	7.43	7.51	7.49
Average size of family*	No.	5.47	5.08	5.18
Male members	No.	3.00	2.86	2.89
Female members	No.	2.47	2.22	2.29
No. of family labor (no.)	Male	2.2	2.1	2.1
	Female	1.8	1.7	1.7
	Total	4.0	3.8	3.8
Participation in labor market (no.)	Male	1.1	0.7	0.8
	Female	0.8	0.5	0.6
	Total	1.9	1.2	1.4

* includes children

Table 11. Occupational structure of households.

Item	Description	MTW (N=90)	WMH (N=270)	Pooled (N=360)
Main Occupation	1.Agriculture	89	270	359
	2.Livestock	1	0	1
Secondary Occupation	1.Agriculture	1	0	1
	2. Livestock	30	143	173
	3. Salaried employee	4	16	20
	4. Income from rentals	4	4	8
	5. Non-farm labor	35	45	80
	6. Others	8	9	17
	7. None	8	53	61
Caste category	1.OC	45	132	177
	2.OBC	16	62	78
	3.SBC	0	1	1
	4.SC	8	24	32
	5.ST	2	11	13
	6.NT	19	40	59

Open Caste (OC) communities constituted about one-half of the sample in both the regions. Other backward castes (OBC) and nomadic tribes (NT) were the other major caste groups in the sample. The Scheduled Castes (SC) and Scheduled Tribes (ST) together had a share of only 12.5% in the combined sample from both the regions.

6.1.3 Landholding particulars

The size of landholdings was larger in MTW by about 0.585 ha than in WMH region (Table 12). In both the regions, leased-in land was far less than leased-out or fallow land. As a result, operational holdings were smaller than ownership holdings in both the regions. Both the irrigated as well as the rainfed fractions of sample farmers was larger in the case of MTW than in WMH. The pooled operational holding of the sample farmers was 2.23 ha, with 43% area under irrigation and the remaining under rainfed cultivation.

Table 12. Average landholding size of sample.

Item (ha per HH)	Type	MTW (N=90)	WMH (N=270)	Pooled (N=360)
Total own landholding	Irrigated	1.143	0.897	0.959
	Rainfed	1.631	1.291	1.376
	Total	2.773	2.188	2.335
Leased-in land	Irrigated	0.004	0.006	0.006
	Rainfed	0.000	0.023	0.017
	Total	0.004	0.029	0.023
Leased out/permanent fallow	Irrigated	0.000	0.007	0.006
	Rainfed	0.229	0.092	0.127
	Total	0.229	0.100	0.132
Operated landholding	Irrigated	1.147	0.896	0.959
	Rainfed	1.401	1.222	1.267
	Total	2.548	2.118	2.226

6.1.4 Cropping systems and cropping patterns

Pearl millet is normally grown in poor to medium grade soils. Except when these soils have irrigation facilities, a second crop cannot normally be grown after pearl millet is grown on these soils. About 55% of the area under pearl millet is left fallow in the subsequent season (Table 13). About 26% of the area is planted to postrainy season sorghum after pearl millet. Wheat is grown in 11% of the area after it. Onion and chickpea are the other postrainy season crops taken after pearl millet. Maize, peas and potato are also grown after pearl millet in insignificant areas.

Table 13. Major pearl millet cropping systems in Maharashtra.

Cropping system type	Proportion of total pearl millet area (%)
Pearl millet – fallow	55.1
Pearl millet–sorghum	26.3
Pearl millet–wheat	10.6
Pearl millet– onion	4.7
Pearl millet–chickpea	2.9
Pearl millet–maize	0.1
Pearl millet–peas	0.1
Pearl millet-potato	0.1

6.1.5 Importance of pearl millet in the sample

Pearl millet occupied about one-fourth of the area in MTW during the rainy season, while it had a share of 40% in the cropping pattern of WMH during the rainy season (Table 14). Cotton occupied the highest area in the MTW sample. Maize and sugarcane were the other important crops in MTW. Soybean, groundnut and green gram were the minor crops in MTW. In WMH, maize and cotton were the major crops next to pearl millet. Soybean, onion, pomegranate, green gram, groundnut and sugarcane were the crops of minor importance in the WMH region sample. The extent of fallow land was higher in WMH than in MTW.

Nearly three-fourths of the land remained fallow in MTW region during the postrainy season (see Table 15). But in WMH, about two-thirds of the land remained fallow. In both the regions, sorghum was the most important crop in the postrainy season. Wheat, chickpea and onion are the other crops grown in MTW in that order. The same crops were grown in WMH, but the order of importance was different with –onion, wheat and chickpea as the sequence.

Table 14. Average rainy season cropping patterns of sample.

Crops (ha per HH)	MTW (N=90)	WMH (N=270)	Pooled (N=360)
Pearl millet	0.66	0.86	0.81
Cotton	1.09	0.28	0.49
Maize	0.26	0.32	0.30
Sugarcane	0.24	0.03	0.08
Soybean	0.09	0.07	0.07
Onion	0.00	0.05	0.04
Pomegranate	0.00	0.05	0.04
Green gram	0.01	0.04	0.03
Groundnut	0.03	0.03	0.03
Others	0.04	0.10	0.08
Fallow	0.16	0.30	0.27
Total	2.58	2.12	2.23

Table 15. Average postrainy season cropping pattern of sample.

Crops (ha per HH)	MTW (N=90)	WMH (N=270)	Pooled (N=360)
Sorghum	0.37	0.28	0.30
Onion	0.05	0.20	0.16
Wheat	0.12	0.14	0.14
Chickpea	0.10	0.05	0.06
Others	0.01	0.04	0.03
Fallow	1.91	1.41	1.53
Total	2.56	2.12	2.22

The total cropped area of the sample households in MTW during the cropping year was 275.51 ha (Table 16), and 78.9% of it was devoted solely to *kharif* crops. Pearl millet area (59.11 ha) formed 27.19% of the rainy season cropped area (217.41 ha). It formed 21.45% of the total cropped area in MTW region. Relatively, pearl millet was more important to the sample households of WMH. The area under pearl millet on the sample farms in WMH was 232.59 ha. It formed 47.46% of the cropped area in the rainy season (490.08 ha), suggesting that nearly one half of the cropped area in the rainy season was under pearl millet. Its share in the total cropped area (683.81 ha) was more than one-third (34.01%). In the pooled sample, pearl millet occupied more than 41% of the rainy season cropped area and more than 30% of the total cropped area. These figures suggest that pearl millet plays an important role in the cropping pattern of the sample farmers.

Table 16. Importance of pearl millet in sample households.

Item	MTW (N=90)	WMH (N=270)	Pooled (N=360)
Total cropped area (ha)	275.51	683.81	959.31
Area under kharif (rainy) (ha)	217.41	490.08	707.49
Area under rabi (postrainy) (ha)	58.10	193.72	251.82
Pearl millet cropped area (ha)	59.11	232.59	291.70
% of Pearl millet in rainy season area	27.19	47.46	41.23
% of Pearl millet in total cropped area	21.45	34.01	30.40

6.1.6 Household assets

The asset values were much higher in MTW region than in WMH, which is mainly on account of land value, particularly of the irrigated land (Table 17). Apart from land value, the value of farm buildings was also higher in MTW. The value of all other assets, such as livestock, farm equipment and consumer durables were higher in WMH region. Owing to the difference in land value of USD 32,810, the value of assets in MTW was higher by 45% over the same in WMH. The pooled average value of assets of a sample household was quite high at USD 82,760.

6.1.7 Household incomes

The average household income was also higher in MTW than in WMH by USD 382 per year (Table 18). The income earned from agriculture was the main reason for this difference. This item alone contributed to a difference of USD 223. It was noted that MTW had higher value of land asset, because of better quality land or better irrigation facilities. Income from both farm labor as well as non-farm labor was also higher in MTW. Income from business and rental income from farm equipment were also higher in MTW. WMH region earned marginally higher incomes from livestock, salaried jobs and out-migration. The pooled annual average household income of the sample households was USD 2798. For a family of 5.18 members, it works out to USD 7.67 per day. The per capita income works out to USD 1.48 per day.

Table 17. Average value of household assets across regions.

Item ('000 USD per HH)	MTW (N=90)	WMH (N=270)	Pooled* (N=360)
Total land value	96.56	63.75	71.95
1.Irrigated	61.51	32.88	40.03
2. Dryland	33.41	27.66	29.10
3. Fallow land	1.65	3.21	2.82
Total livestock value	1.63	1.84	1.79
Draft	0.58	0.40	0.45
Buffaloes	0.36	0.42	0.41
Others	0.69	1.02	0.93
Total farm equipment	1.62	2.59	2.35
Total farm buildings	6.51	4.13	4.73
Total consumer durables	1.72	2.01	1.94
Total assets value	108.04	74.32	82.76

*1 USD = INR 55

Table 18. Annual average household income across regions.

Source of Income ('000 USD)	MTW (N=90)	WMH (N=270)	Pooled* (N=360)
Agriculture	1.663	1.440	1.496
Farm labor	0.392	0.221	0.264
Non-farm labor	0.155	0.098	0.112
Livestock and hiring of bullocks	0.334	0.397	0.381
Caste occupation	0.000	0.000	0.000
Business	0.206	0.121	0.142
Govt. development programs	0.091	0.076	0.080
Salaried	0.139	0.231	0.208
Rental income on farm equipment	0.081	0.070	0.072
Out migration	0.020	0.023	0.022
Others	0.002	0.026	0.020
Grand total	3.084	2.702	2.798

*1 USD = INR 55

6.1.8 Household consumption expenditure

The estimated consumption expenditure of the household was also higher in the case of the MTW sample; it was USD 1798 per year (Table 19). Compared to the consumption expenditure of USD 1726 per year in WMH, it was higher by only 4.2%. With regard to household income, there was a difference of 14% between MTW and WMH, whereas in terms of consumption expenditure, the difference got narrowed down to only 4%. MTW led WMH in case of both food and non-food expenditure. There was a difference of 8% in non-food expenditure between the two regions, while the difference in food expenditure was only 2% between the two regions. While the families in WMH spent slightly more on cereals and pulses, the families from MTW spent more on milk and milk products, non-vegetarian items and other food items. The pooled average consumption expenditure was USD 1743 per year. The family expenditure per day was USD 4.78 and the per capita expenditure worked out to USD 0.92 per day. The households fall in the category of poor as the World Bank defines all households with less than per capita expenditure of one dollar per day as poor.

Table 19. Consumption expenditure across regions.

Item ('000 USD per HH)	MTW (N=90)	WMH (N=270)	Pooled* (N=360)
Rice	0.022	0.026	0.025
Wheat	0.056	0.065	0.062
Pearl millet	0.075	0.077	0.076
Other cereals	0.044	0.030	0.034
Pigeonpea	0.033	0.032	0.033
Chickpea	0.027	0.027	0.027
Other pulses	0.024	0.033	0.030
Milk	0.184	0.168	0.172
Other milk products	0.003	0.001	0.002
Other food expenditure	0.505	0.481	0.487
Non-food expenditure	0.112	0.124	0.121
Non-vegetarian	0.047	0.045	0.045
Health	0.108	0.104	0.105
Clothing	0.126	0.103	0.109
Education	0.096	0.094	0.095
Ceremonies	0.077	0.076	0.076
Entertainment/travel	0.110	0.093	0.097
Others	0.149	0.147	0.147
Grand total	1.798	1.726	1.743

*1 USD = INR 55

6.1.9 Utilization of pearl millet in sample households

A typical household in MTW produced 1099 kg of pearl millet grain and 1444 kg of fodder (Table 20). These levels were higher at 1310 kg of grain and 1709 kg of fodder in WMH due to a higher area under the crop. The pooled average production per household was 1257 kg of grain and 1639 kg of fodder. As the farmers have shifted totally to hybrids, no part of production was saved for seed. Only 1.4% of grain and 4.0% of fodder was given out as gift or kind payment. About 30% of grain was used for consumption, and about 71% of fodder produced was used as feed. Moreover, 55% of the grain produced and 7% of fodder produced was sold in the market. About 13% of grain and 16% of fodder was kept in store.

Table 20. Pearl millet output utilization in 2012-13.

	MTW (N=90)		WMH (N=270)		Pooled (N=360)	
Item (kg per HH)	Grain	Fodder	Grain	Fodder	Grain	Fodder
Total production	1099	1444	1310	1709	1257	1639
Saved as seed	0	0	0	0	0	0
Gift/kind payments	31	73	12	64	17	66
Used as food	438	0	351	39	372	29
Used as feed	0	1167	18	1156	14	1159
Sold in market	481	57	756	141	687	120
In store	149	147	173	309	167	265

The costs of marketing incurred by the farmers during 2012-13 are furnished in Table 21. The cost of marketing 100 kg of pearl millet grain was USD 1.42 in MTW and USD 1.24 in WMH. The cost of marketing fodder was much higher in WMH at USD 0.12 per 100 kg when compared with USD 0.03 per 100 kg in MTW. The pooled average cost of marketing in the sample was USD 1.28 per 100 kg of grain and USD 0.10 per 100 kg of fodder. The average quantity sold was higher in MTW than in WMH. The pooled average quantity sold was 25 kg per household and 9 kg of fodder.

Table 21. Pearl millet marketing cost in 2012-13.

	MTW (N=90)		WMH (N=270)		Pooled (N=360)	
Type of cost (USD per 100 kg)	Grain	Fodder	Grain	Fodder	Grain	Fodder
Bagging cost	0.20	0.00	0.21	0.02	0.21	0.01
Transportation cost	0.30	0.00	0.30	0.06	0.30	0.05
Commission agent cost	0.10	0.00	0.13	0.00	0.13	0.00
Market fee	0.76	0.00	0.51	0.00	0.56	0.00
Labor cost	0.06	0.03	0.09	0.04	0.08	0.04
Marketing cost	1.42	0.03	1.24	0.12	1.28	0.10
Avg. qty sold/HH (kg)	35	13	21	7	25	9

6.2 Technology adoption and impacts

The pattern of adoption of pearl millet 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:

6.2.1 Pattern of first adoption and sources of seed

ICTP 8203 was released in 1988, its adoption started picking up in 1997 in Maharashtra and it reached a peak by 2001 (Figure 15). Mahyco 204 also started off in 1997 and attained its peak in 2001 as well, as is the case of ICTP 8203. Mahyco 204 remained in contention among farmers and again showed its strength in 2010 before petering out in subsequent years. Pioneer 86 M 32 started off in 1999 and attained considerable presence in the years of 2008 and 2009, before fizzling out in subsequent years. The adoption of Pioneer 86 M 33 started off only in 2009 but quickly reached a peak by 2011. Nirmal 9 started showing its presence in 1999 but has really become active only after 2003, attaining a small peak in 2005. It remained in contention till 2011.

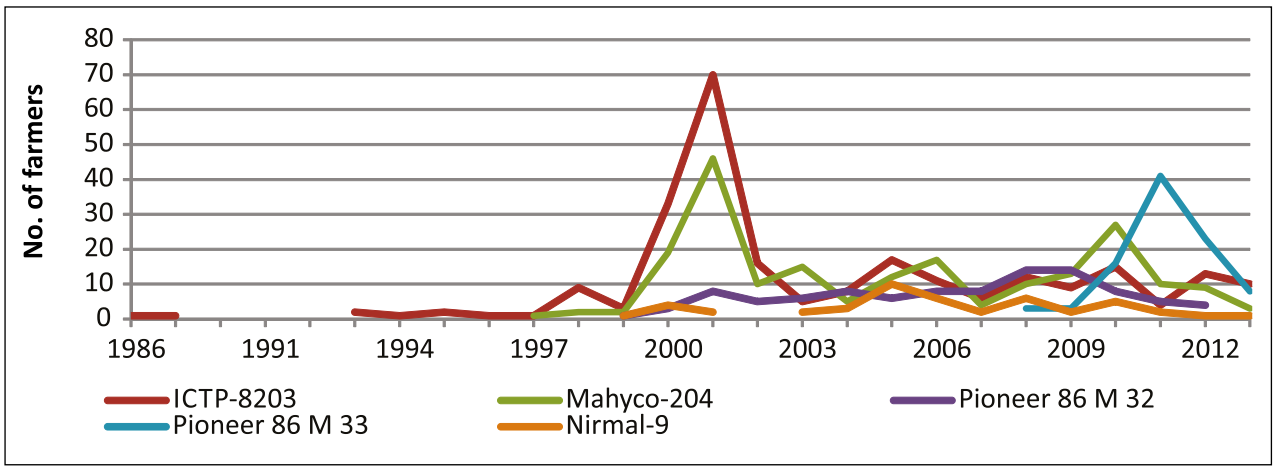

Figure 15. First adoption pattern of major pearl millet improved cultivars in the sample.

Table 22. First adoption pattern of pearl millet cultivars in Maharashtra*.

Year	ICTP 8203	Mahyco 204	Pioneer 86 M 32	Pioneer 86 M 33	Nirmal 9	Mahyco 163	MLBH 308
1986	1						
1988	1	1					
1991	1						
1993	2						
1994	1						
1995	2	2				1	
1996	1						
1997	1	1			1		
1998	9	2				2	
1999	3	2	1		1		
2000	33	19	3		4	2	
2001	70	46	8		2	6	2
2002	16	10	5			2	1
2003	5	15	6		2		5
2004	8	5	8		3	1	1
2005	17	12	6		10	2	2
2006	11	17	8		6	3	2
2007	6	4	8		2		3
2008	12	10	14	3	6	3	2
2009	9	13	14	3	2	4	2
2010	15	27	8	16	5	7	6
2011	4	10	5	41	2	2	1
2012	13	9	4	23	1	1	5
2013	10	3		8	1	1	1
Total	251	208	98	94	48	37	33

** Represents no. of sample farmers first adopted particular improved cultivar.*

The first adoption of ICTP 8203 started in 1988 but reached a peak in first adoption in 2001, thus taking 13 years to become popular (Table 22). Mahyco 204 similarly took six years from 1995 to 2001 to attain a peak of first adoption. Pioneer 86 M 32 took 9–10 years, between 1999 and 2008–2009 to reach a peak in first adoption. Similarly, Nirmal 9 took eight years between 1997 and 2005 to reach its first adoption peak. Mahyco 163 took six years to reach first peak, lay low for some years and again scaled the peak of first adoption after another nine years. MLBH 308 reached a small peak in two years between 2001 and 2003. It has been in the market since then and again became popular after seven years in 2010 and again in 2012. The recent hybrid, Pioneer 86 M 33, took only three years to attain a peak of first adoption between 2008 and 2011.

In MTW region, Mahyco 204 quickly become prominent in 1999 itself and reached a peak in 2001 (Figure 16). It faced ups and downs but remained a prominent contender till 2011. It established local peaks again in 2006 and 2010. ICTP 8203 was taken up by farmers in 1996, but it reached a peak in 2000 only before Mahyco 204 came into strength. It was not adopted by the sample farmers again till 2004. It remained in contention till 2010. Pioneer 86 M 32 made its appearance in 1999 and witnessed an uptake by 2001, but farmers' interest in it waned after 2002. It again came into contention in 2006 and again witnessed an uptick in 2009. It is still in demand from some farmers till 2012. MLBH 308 entered the market in 2005 and saw a chequered performance until 2009. It attained a small peak in 2010 and is still in contention. Pioneer 86 M 33 came with a bang in 2010 and reached a peak in the next year itself.

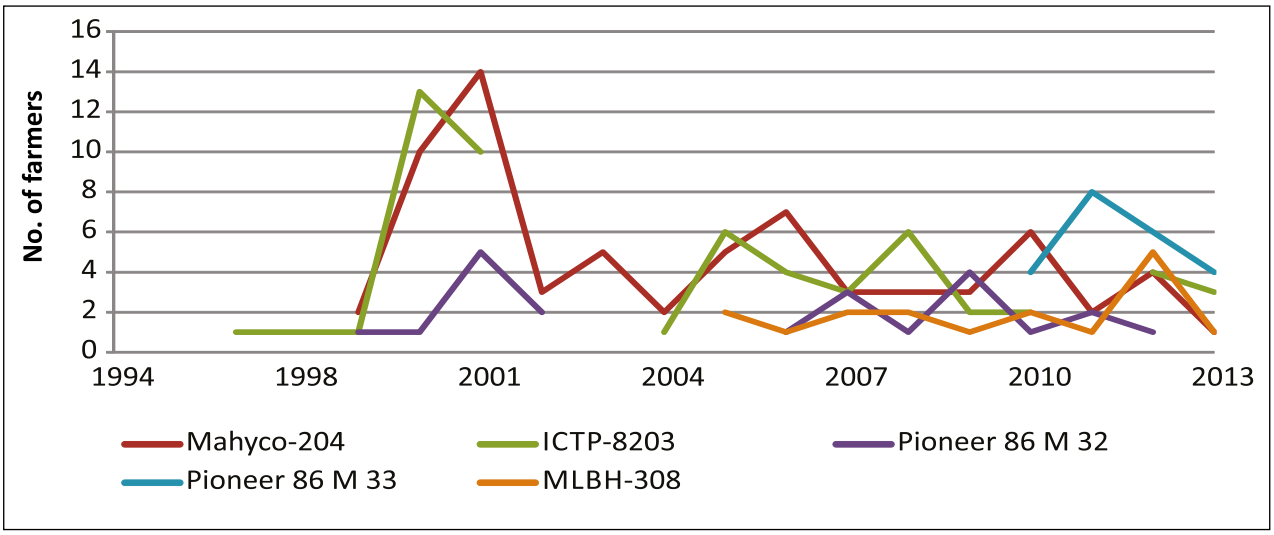

Figure 16. First adoption pattern of sample farmers in MTW region.

WMH saw both Mahyco 204 and ICTP 8203 attaining peak adoption in 2001 (Figure 17). The acceptance for ICTP 8203 was more in WMH and it dominated the scene till 2005. Both of them are still in contention but Mahyco 204 overtook ICTP 8203 after 2008. Pioneer 86 M 32 came on the scene in 2000 and had a steady presence till 2012. It also recorded a small peak in 2008. Mahyco 163 was another variety which has been showing its presence off and on in WMH between 2000 and 2011. Pioneer 86 M 33 started in 2008 and soon took off to reach a peak in 2011.

Table 23 summarizes the data depicted in the three graphs, Figures 15 to 17. In MTW, the cumulative figures of first adoption showed that Mahyco 204 had an edge over ICTP 8203. Nevertheless, both were in contention in all the five sub-periods, showing that they have their own niche pockets of adoption all through the study period. As many as 71 out of 90 sample farmers adopted Mahyco 204, while this cumulative score was 58 for ICTP 8203. Pioneer 86 M 32 was introduced a few years after the above two and was in contention in all the subsequent periods, with a cumulative score of 22 adopters out of a sample of 90 farmers. Pioneer 86 M 33 also had the same cumulative score of 22, although it came in only after 2005. MLBH 308 was introduced after 2000 but it also attained a respectable cumulative score of 20. In the case of WMH, ICTP 8203 had an upper hand over Mahyco 204 in four out of the five sub-periods under study. Mahyco 204 showed its superiority only during 2006-10. In all, ICTP 8203 had a cumulative score of first adopters reaching 193 in a sample of 270. Mahyco 204 followed it with a cumulative score of 137, just crossing the halfway mark of the sample total. Pioneer 86 M 32 had a slight edge over Pioneer 86

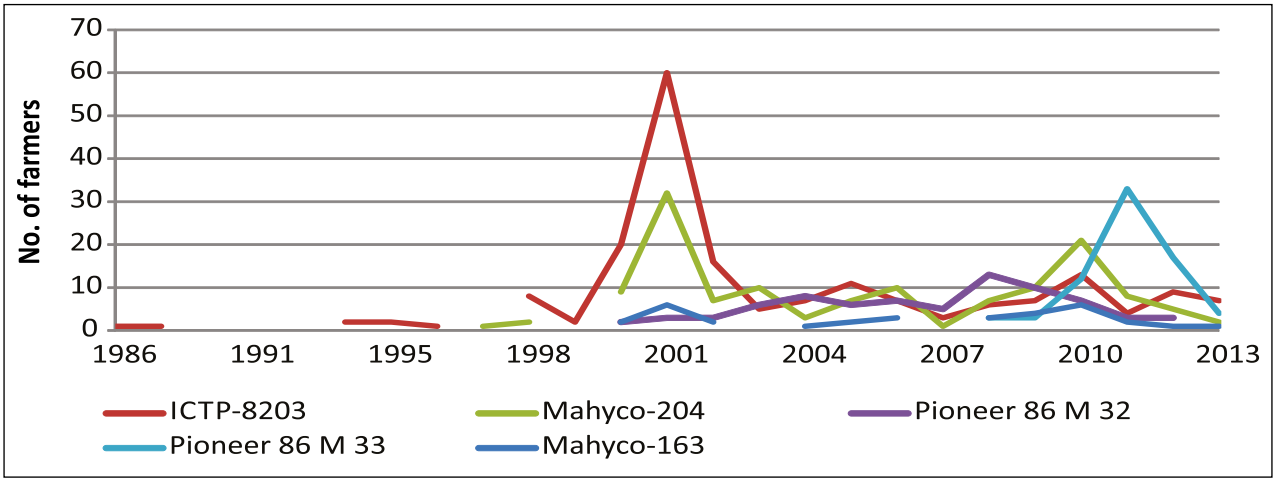

Figure 17. First adoption pattern of sample farmers in WMH region.

M 33, because of its long presence in the market. Clearly, Pioneer 86 M 33 is the star in the latest period. Mahyco 163 was also in the market for quite a long period but it could reach only 12% of the sample. In the pooled sample, ICTP 8203 retained its top place among the cumulative adopters. Nearly 70% of the sample farmers adopted it at some time or the other. In contrast to it, Mahyco 204 reached only 58% of the sample. Both Pioneer 86 M 32 and Pioneer 86 M 33 reached more than 25% of the sample each. Nirmal 9 could reach about 13% of the sample. While ICTP 8203 dominated the scene till 2005, Mahyco 204 reached the top spot during 2006-10. After 2010, it is Pioneer 86 M 33 that is the clear winner.

Table 23. Pattern of first adoption of improved cultivars across two regions.

	MTW (N=90)					WM (N=270)					Pooled (N=360)				
Year	ICTP 8203	Mahyco 204	MLBH 308	P 86 M 32	P 86 M 33	ICTP 8203	Mahyco 204	P 86 M 32	P 86 M 33	Mahyco 163	ICTP 8203	Mahyco 204	Nirmal 9	P 86 M 32	P 86 M 33
Before 1995	1	1	0	0	0	7	2	0	0	1	8	3	0	0	0
1996-2000	16	12	0	2	0	31	12	2	0	4	47	24	6	3	0
2001-2005	17	29	5	7	0	99	59	26	0	11	116	88	17	33	0
2006-2010	17	22	8	10	4	36	49	42	18	16	53	71	21	52	22
After 2010	7	7	7	3	18	20	15	6	54	4	27	22	4	9	72
Total	58	71	20	22	22	193	137	76	72	36	251	208	48	98	94

Information about the new cultivars in the year of their first adoption was predominantly received from private shop/seed dealer (Table 24). Fellow farmers and newspaper/radio/TV were the other minor sources that give information about the new variety/hybrid in the year of their first adoption. Government extension, farmer associations, on-farm trials/demonstrations, research centers/universities reached only a very insignificant proportion of the sample farmers to give information about the new varieties in the years of their first adoption.

The important source of seed supply in the year of first adoption was also from local trader/agro-dealers (see Table 25). Ninety-five of sample farmers obtained seed from traders/agro-dealers. Some obtained them from local seed producers, government agencies and non-governmental organizations. Farmers' clubs, other farmers, extension demonstration plots and research stations/university could hardly reach 1 or 2% of the farmers.

Table 24. Major sources of information for first adoption of improved cultivars.

Source of information (%)	MTW	WMH	Pooled
1. Govt. extension	0.00	1.82	1.36
2. Farmer association	0.00	0.64	0.48
3. NGO	0.00	0.11	0.08
4. Research center/university	0.00	0.53	0.40
5. On-farm trials/demos	0.00	0.64	0.48
6. Fellow farmer	8.92	7.80	8.08
7. Private shop/seed dealer	91.08	83.97	85.76
8. Newspaper/radio/TV	0.00	4.49	3.36
Total	100.0	100.0	100.0

Table 25. Sources of seed for first adoption of pearl millet improved cultivars.

Source of seed (%)	MTW	WMH	Pooled
1. Research PVS/Universities	0.00	0.13	0.10
2. Extension demo plots	0.00	0.53	0.38
3. Farmer club/villagers	1.75	0.00	0.48
4. Local seed producers	0.35	1.98	1.53
5. Local trader or agro-dealers	96.14	94.99	95.31
6. Farmer-to-farmer seed exchange	0.35	0.53	0.48
7. NGOs	1.40	0.53	0.77
8. Govt. agency	0.00	1.32	0.96
Total	100.0	100.0	100.0

Table 26. Reasons for growing pearl millet.

Reasons (mean weight out of 100)	MTW (N=90)	WMH (N=270)	Pooled (N=360)
Crop rotation	3	4	4
Fodder purpose	22	22	22
Grain purpose	68	64	65
Suitable to soil and climate	7	10	9

The sample farmers were asked to indicate the primary reason for growing pearl millet. About two-thirds of them in both regions indicated that they grow it mainly for grain purpose (Table 26). Only 22% of sample farmers said that they were primarily growing it for the purpose of fodder. About 9% said that they are growing it as it is best suited to their soil and climate. Only 4% opined that they were growing it for the purpose of crop rotation.

6.2.2 Adoption of pearl millet improved cultivars

The pearl millet cropped area allocation under different improved cultivars by sample farmers was captured during primary household survey. The cropped area allocations under different improved cultivars were also obtained for last three seasons for deeper understanding about cultivar preferences. Even in recent years, 2010-11 and 2011-12, ICTP 8203 occupied the top position in terms of the area planted with it in MTW, followed by Mahyco 204 in 2010-11 and Pioneer 86 M 33 in 2011-12 (Table 27). In 2012-13, Pioneer 86 M 33 was the variety with maximum area coverage, followed by Mahyco 204 and MLBH 308. In the pooled data over the three years period also, these four varieties – ICTP 8203, Mahyco 204, Pioneer 86 M 33 and MLBH 308 – occupied the top places. Varun 666, B2301 Jai Kisan, GK 1044 and Nirmal 9 were hybrids that each had more than 3% share. Dhaanya 7872, Pioneer 86 M 32 and Nirmal 40 were the other hybrids in contention.

In WMH, the composite variety ICTP 8203 still rules the roost in all the three years for which data on pearl millet area were collected from the sample farmers (Table 28). Mahyco 204 was the second-ranking hybrid in terms of area coverage in 2010-11, but in the subsequent two years, Pioneer 86 M 33 displaced it and pushed it to third spot. Pioneer 86 M 32 has occupied third place in 2010-11, but gradually lost importance in the next two years. Dhaanya 7872 and Panchaganga 510 gained ground steadily over the three years in terms of area coverage. When the data over the three years were pooled, ICTP 8203 was the variety with the highest coverage of area. Mahyco 204 and Pioneer 86 M 33 occupied the second and third positions respectively. Pioneer 86 M 32 and Dhaanya 7872 also covered more than 5% of pearl millet area of the sample farmers. Panchaganga 510, Mahyco 163 and GK 1044 were the other hybrids with some notable area coverage. Nirmal 9 and MLBH 308 were the other hybrids in contention, although they are losing area over time.

Table 27. Allocation of area under pearl millet cultivars in MTW region.

Cultivar name	Area in 2010-11 (ha)	Area in 2011-12 (ha)	Area in 2012-13 (ha)	Pooled (ha)
ICTP 8203	15.38	12.96	6.88	11.7 (19.0)
Mahyco 204	13.36	8.70	9.31	10.5 (17.0)
Pioneer 86 M 33	4.66	9.11	10.12	8.0 (13.0)
MLBH 308	7.89	6.07	8.70	7.6 (12.3)
Varun 666	4.05	4.45	3.64	4.0 (6.5)
B2301 Jai Kisan	1.62	2.43	3.44	2.5 (4.1)
GK 1044	2.23	2.23	2.02	2.2 (3.6)
Nirmal 9	2.43	2.43	1.21	2.0 (3.2)
Dhaanya 7872	2.02	2.43	1.21	1.9 (3.1)
Pioneer 86 M 32	2.02	2.02	1.21	1.8 (2.9)
Nirmal 40	1.62	1.62	0.00	1.1 (1.8)
Others	7.29	7.69	10.53	8.5 (13.8)
Grand total	64.57	62.15	58.30	61.7 (100.0)

Note: Figures in parenthesis indicate percentage to column total

Table 28. Allocation of area under pearl millet cultivars in WMH region.

Cultivar name	Area in 2010-11 (ha)	Area in 2011-12 (ha)	Area in 2012-13 (ha)	Pooled (ha)
ICTP 8203	71.7	60.1	70.2	67.3 (29.9)
Mahyco 204	44.1	41.1	38.3	41.2 (18.3)
Pioneer 86 M 32	27.1	18.2	5.1	16.8 (17.5)
Pioneer 86 M 33	16.2	41.9	44.1	34.1 (15.2)
Dhaanya 7872	10.7	12.3	15.2	12.7 (5.6)
Panchaganga 510	6.5	8.9	11.3	8.9 (4.0)
Mahyco 163	7.7	8.9	8.5	8.4 (3.7)
GK 1044	8.1	5.2	5.2	6.2 (2.8)
Nirmal 9	6.1	4.5	1.2	3.9 (1.7)
MLBH 308	3.4	2.6	1.4	2.5 (1.1)
Others	21.0	19.6	28.3	23.0 (10.2)
Grand total	222.6	223.4	228.9	225.0 (100.0)

Note: Figures in parenthesis indicate percentage to column total

The area coverage by different pearl millet hybrids and varieties in the pearl millet area allocated by the pooled sample farmers in Maharashtra is illustrated in Table 29. The pooled data also reflected the same trends as in WMH, as it has 75% share in the total sample. The composite variety ICTP 8203 retained its preeminent position in all the three years. Mahyco 204 occupied the second place during 2010-11, but yielded its place to Pioneer 86 M 33 in the next two years. But, in the data pooled over years, Mahyco 204 retained the second position after ICTP 8203. Pioneer 86 M 32 had larger coverage in 2010-11 than Pioneer 86 M 33, but this position got reversed in the next two years. In the pooled data, Pioneer 86 M 33 and Pioneer 86 M 32 accounted for third and fourth places in terms of area coverage. Dhaanya 7872, MLBH 308, Panchaganga 510, Mahyco 163 and GK 1044 were the next important set of hybrids with considerable area. Nirmal 9 and Varun 666 were the other notable hybrids with some area coverage. All other hybrids and varieties together had a share of about 12%.

Table 29. Allocation of area under pearl millet cultivars in Maharashtra.

Cultivar name	Area in 2010-11 (ha)	Area in 2011-12 (ha)	Area in 2012-13 (ha)	Pooled (ha)
ICTP 8203	87.04	73.08	77.13	79.1 (27.6)
Mahyco 204	57.49	49.80	47.57	51.6 (18.0)
Pioneer 86 M 33	20.85	51.01	54.25	42.0 (14.6)
Pioneer 86 M 32	29.15	20.24	6.28	18.6 (6.5)
Dhaanya 7872	12.75	14.78	16.40	14.6 (5.1)
MLBH 308	11.34	8.70	10.12	10.1 (3.5)
Panchaganga 510	6.88	9.31	12.15	9.4 (3.3)
Mahyco 163	8.50	9.72	9.31	9.2 (3.2)
GK 1044	10.32	7.49	7.29	8.4 (2.9)
Nirmal 9	8.50	6.88	2.43	5.9 (2.1)
Varun 666	4.05	4.45	3.64	4.0 (1.4)
Others	30.36	30.16	40.69	33.7 (11.8)
Total	287.25	285.63	287.25	286.7 (100.0)

Note: Figures in parenthesis indicate percentage to column total

Besides household surveys, village questionnaires were also administered to a group of villagers consisting of village leaders, progressive farmers, government officers, school teachers etc. Group members responding to community surveys were asked to give their estimates of area under different pearl millet hybrids/varieties in the village. The responses from the community surveys were pooled to get the distribution of pearl millet area under different hybrids/varieties in the sample villages. Data from the community surveys are presented in Table 30. The composite variety ICTP 8203 was credited with having the largest share of 26% in the pearl millet area in the sample villages. Pioneer 86 M 33 and Mahyco 204 have shares of 17 and 16% respectively. Other hybrids, such as GK 1044, MDBH 318, Devgen 308 and Nirmal 9 have shares ranging between 7 and 4% each. Dhaanya 7872, Mahyco 163, Mahyco 2240, Mahyco 2210, Pioneer 86 M 33, Panchaganga 510 and Manik-1003 have shares of 1 to 3% each. All other hybrids – Advanta 931, Shakti, Spriha S 301, Kaveri Superboss, Yashoda 30Y93 and Shraddha – have shares between 0.5% and 1%. All other hybrids have shares less than 0.5% each. The area under modern varieties added up to 99.59%, and barely 0.41% was under local varieties.

ICTP 8203, Mahyco 204 and Pioneer 86 M 33 were popular in both MTW and WMH regions. Devgen 308 and Mahyco 2210 were also popular in MTW region, but not in WMH. In the same way, GK 1044 and MDBH 318 occupied considerable areas in WMH, but not in MTW. Yashoda 30Y93 covered more than 3% area in MTW, while Nirmal 9, Mahyco 163 and Dhaanya 7872 have 3% or more areas under each of them in WMH.

The estimates of pearl millet areas under different varieties were assessed by three different methods (Expert elicitation vs Focus group meetings vs Household survey) and the results are summarized in Table 31. Several experts were asked to give their estimates of areas under different improved varieties of pearl millet in Maharashtra. While they could not give exact estimates of areas covered by different varieties, they said that about 80% of the area was under improved cultivars, while the remaining area was under traditional varieties. They seem to have placed ICTP 8203 under traditional varieties, as it is not a hybrid. The second method of estimating areas under different varieties was through community surveys conducted in all the sample villages of the study. These surveys estimated that 25.86% area was under the composite variety ICTP 8203. They indicated that about 0.41% area was under local varieties of pearl millet. The remaining 73.73% area was perceived to be under different hybrids/varieties of pearl millet. Pioneer 86 M 33 and Mahyco 204 were the most popular hybrids, distantly followed by GK 1044, MDBH

Table 30. Adoption of pearl millet improved cultivars by community surveys[1].

S.No	Cultivar	MTW (% area)	WMH (% area)	Pooled (% area)
1	ICTP 8203[2]	25.10	26.01	25.86
2	Pioneer 86 M 33	16.33	17.31	17.15
3	Mahyco 204	19.46	14.97	15.71
4	GK 1044	0.19	7.88	6.62
5	MDBH 318	0.00	7.39	6.17
6	Devgen 308	17.90	2.09	4.69
7	Nirmal 9	0.53	4.74	4.04
8	Dhaanya 7872	1.26	2.96	2.68
9	Mahyco 163	0.00	3.08	2.57
10	Mahyco 2210	7.55	0.41	1.58
11	Mahyco 2240	1.08	1.67	1.57
12	Pioneer 86 M 32	0.90	1.33	1.26
13	Panchaganga 510	0.39	1.23	1.10
14	Manik (M 1003)[2]	0.00	1.20	1.01
15	Advanta 931	0.79	0.89	0.87
16	Shakti	0.00	0.98	0.82
17	Spriha S 301	0.09	0.96	0.81
18	Kaveri super boss	0.00	0.95	0.79
19	Yashoda 30Y93	3.37	0.20	0.73
20	Shraddha[2]	0.00	0.74	0.62
21	Tilak (DB 2013)	0.45	0.50	0.49
22	Tulja (Local)	0.00	0.51	0.43
23	B2301 (Zuari)	0.31	0.41	0.40
24	Others hybrids	0.81	0.24	0.33
25	Mahyco 267	1.95	0.00	0.32
26	Varun 666	1.47	0.00	0.24
27	Western M45	0.00	0.20	0.17
28	ProAgro 9330	0.06	0.19	0.17
29	Devgen 504	0.00	0.19	0.16
30	Nirmal 40	0.00	0.19	0.16
31	ProAgro 7701	0.00	0.07	0.06
	Area under total MVs	100	99.5	99.59
	Area under locals	0.00	0.5	0.41
	Total area	100.00	100.00	100.00

[1.] Survey method: Focus group meetings

[2] Public-bred cultivars but supported by private sector seed multiplication

318, Devgen 308, Nirmal 9 and so on. The actual household survey estimated that 27.6% area was under ICTP 8203 and the remaining area under different pearl millet hybrids. It is estimated that the maximum area was under Mahyco 204 and Pioneer 86 M 33, distantly followed by Dhaanya 7872, Devgen 308, Mahyco 163, GK 1044, Nirmal 9 etc. In the community surveys, MDBH 318 and Mahyco 2210 figured but these two hybrids did not occupy areas as per the household surveys. It may be concluded that the expert opinion gives only a vague idea. Community surveys give some reasonable estimates and they can be resorted to when time and cost are binding constraints. Household surveys give more precise estimates.

Table 31. Comparison of adoption estimates by different methods.

S. No	Cultivar	Expert level (% area)	Community level (% area)	HH level (% area)
1	ICTP 8203		25.86	27.60
2	Pioneer 86 M 33		17.15	14.60
3	Mahyco 204		15.71	18.00
4	GK 1044		6.62	2.90
5	MDBH 318		6.17	0.00
6	DevGen 308	80	4.69	3.50
7	Nirmal 9		4.04	2.10
8	Dhaanya 7872		2.68	5.10
9	Mahyco 163		2.57	3.20
10	Mahyco 2210		1.58	0.00
11	Other hybrids		12.52	23.00
	Area under Total MVs	80.0	99.59	100.00
	Area under locals	20.0	0.41	0.00

Major sources of seeds of pearl millet improved cultivars

The composite variety (ICTP 8203) is still preferred choice of farmers in rainfed tracks of Western Maharashtra. The penetration of hybrids is quite prominent in case of Marathwada region when compared with Western Maharashtra region. Overall, concerted efforts are required in the state to replace significant cropped area under improved varieties with new generation (drought tolerant and high yielding) hybrids to improve the productivity. The average adoption lag observed among prominent cultivator ranged from 6-9 years.

Even during the year (2012-13) of reference for the survey, all the seeds used by the sample farmers were bought from local traders or seed companies in MTW (Table 32). Even in WMH, 92% of the sample farmers accessed pearl millet seed from local traders and seed companies. About 7% of the farmers in this region were provided seed free of cost by the Government department. Local seed producers and farmers' clubs catered to the seed requirement of the remaining 1% of the sample farmers. In the pooled sample, 94% of the farmers accessed the seeds of pearl millet from local traders and seed companies. 5% obtained it from the government agency, while the remaining 1% of farmers got it from local seed producers and farmers' clubs.

Table 32. Sources of seed during 2012-13.

Source of seed (% of farmers accessing)	MTW	WMH	Pooled
1. Research PVS/Univ.	0.00	0.00	0.00
2. Extension demo plots	0.00	0.00	0.00
3. Farmer club/villagers	0.00	0.37	0.27
4. Bought from local seed producers	0.00	0.74	0.55
5. Bought from local trader or seed companies	100.0	92.28	94.25
6. Farmer-to-farmer seed exchange (relative, friend, etc.)	0.00	0.00	0.00
7. Provided free by NGOs	0.00	0.00	0.00
8. Provided free by govt. agency	0.00	6.62	4.93
9. Own seed	0.00	0.00	0.00
10. Subsidized government seed supply	0.00	0.00	0.00
11. Others	0.00	0.00	0.00
Total	100.0	100.0	100.0

6.2.3 Average productivity levels across regions

Sample farmers were asked to indicate the yields of pearl millet they get under different climatic conditions. The responses of the sample farmers in both the regions are presented in Table 33. In both the regions, the perceived grain yield of pearl millet is around 900 kg ha^{-1} under adverse weather conditions. The fodder yield is around 1300 kg ha^{-1}. In a bad year, the grain and fodder yield ratio is 1:1.47. In a normal year, the grain yield is perceived to go up to about 2116 kg ha^{-1}. But the fodder yield is perceived to go up to 2667 kg ha^{-1} only. In a normal year, the grain/fodder ratio falls to 1:1.26. The best yields perceived by the sample farmers in both the regions are around 2801 kg of grain and 3504 kg of fodder per hectare. The grain/fodder ratio fell to 1:1.25 during the best year.

The actual yields obtained by the sample farmers during the years, 2010-11, 2011-12 and 2012-13 are averaged and presented in Table 34. In all the three years, the grain and fodder yields reported were marginally higher in MTW than in WMH. Among the three years, best yields were reported in 2010-11. The pooled average grain yield was 2023 kg of grain and 2543 kg of fodder. The grain/fodder yield ratio was 1:1.26 in that year. The next year, 2011-12, was not as good a year as 2011-12 and the average yields of grain and fodder dropped to 1746 kg and 2292 kg respectively. In that year, the grain/fodder ratio changed to 1:1.31. The year with reference to which the detailed data were collected from the sample farmers was 2012-13 and it turned out to be even worse than 2011-12. The grain yield dropped further in MTW, while it remained the same in WMH. The pooled average yields of grain and fodder dropped further to 1733 kg and 2328 kg respectively. The grain/fodder ratio changed to 1:1.34. The fodder/grain ratio increases in a bad year and it decreases in a good year.

Performance of major pearl millet improved cultivars

The performance of some of the important pearl millet cultivars during 2012-13 is summarized in Table 35 based on farmers' recall. Only ICTP 8203 gave a higher grain yield in MTW than in Western Maharashtra. All the four pearl millet hybrids yielded better in WMH than in MTW. Dhaanya 7872 gave a very poor yield in MTW region. Among all the hybrids, Mahyco 204 gave the best yield in MTW. It was Mahyco 163 that stood out in Western Maharashtra. The average yields of the pooled sample are given in the last column of the table. All the hybrids out-yielded the composite variety, ICTP 8203. Mahyco 163 gave almost twice the yield as the composite variety. Mahyco 163 was followed by Mahyco 204, Pioneer 86 M 33 and Dhaanya 7872.

Yield variability across different climate conditions

The perceived yield distributions of pearl millet in Maharashtra are plotted in graph 18. The grain yield distribution in a bad year is depicted in black color. The yield distribution was leptokurtic during the bad

Table 33. Average pearl millet yields under different climatic situations.

	MTW (kg ha^{-1})		WMH (kg ha^{-1})		Pooled (kg ha^{-1})	
Season type	Grain	Fodder	Grain	Fodder	Grain	Fodder
Bad year	919	1420	893	1286	900	1319
Normal year	2069	2703	2132	2655	2116	2667
Best year	2775	3549	2810	3490	2801	3504

Best year is defined as the highest yield obtained by sample farmer in his field. Bad year is defined as the lowest yield experienced by sample farmer in his field.

Table 34. Average yields of the sample farmers during the last three seasons.

	MTW (kg ha^{-1})		WMH (kg ha^{-1})		Pooled (kg ha^{-1})	
Year	Grain	Fodder	Grain	Fodder	Grain	Fodder
2010-11	2039	2643	2018	2510	2023	2543
2011-12	1855	2522	1709	2215	1746	2292
2012-13	1793	2506	1712	2269	1733	2328

Table 35. Grain yield of major pearl millet improved cultivars, 2012-13.

Major cultivar	MTW (kg ha^{-1})	WMH (kg ha^{-1})	Pooled (kg ha^{-1})
Dhaanya 7872	617.5	1435.7	1344.8
ICTP 8203	1431.7	1222.7	1246.2
Mahyco 163	1729.0	2542.0	2479.5
Mahyco 204	1985.7	2253.7	2186.7
Pioneer 86 M 33	1770.2	1943.5	1905.4

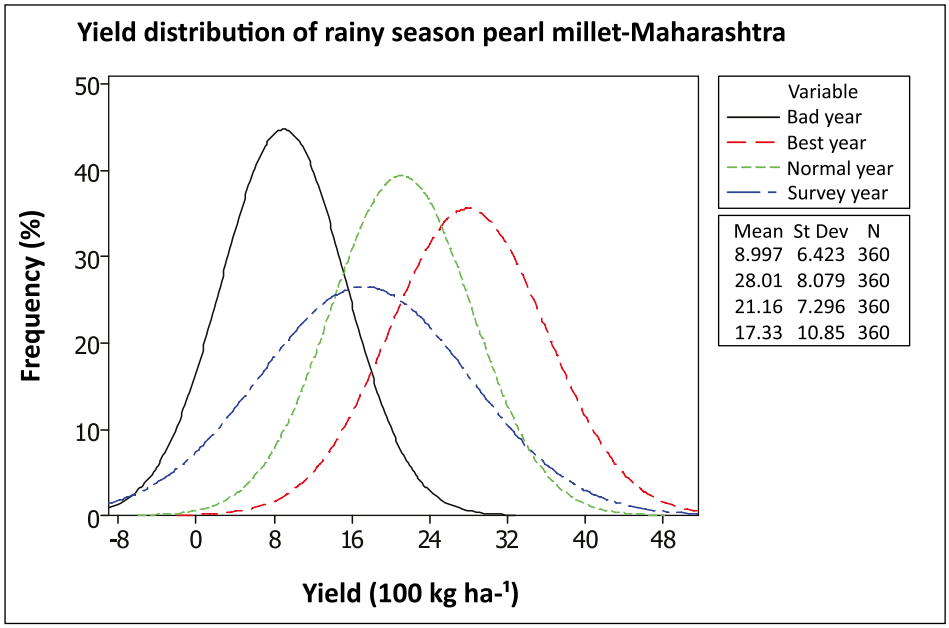

Figure 18. Yield distributions under different climatic condition in Maharashtra.

year. The yield distribution in a normal year was also slightly leptokurtic, although the height of the bell is less than that in a bad year. In the best year, the perceived grain yield resembled normal, although it still remained slightly leptokurtic. But the actual yield distribution in 2012-13, the reference year for the study, was quite normal. This distribution lay between that of a bad year and that of a good year. 2012-13 was actually a sub-normal year and hence the yield distribution lay in between a bad year and a normal year.

In Figure 19, all the perceived grain yield distributions of pearl millet in MTW were more leptokurtic than the corresponding ones in Maharashtra. This usually happens when the number of observations decreases. In the case of MTW also, the leptokurtic nature showed a decline as we moved from a bad year to a normal year and finally to the best year. The actual yield distribution in 2012-13 was closer to normal and lay between the distributions of a bad year and normal years. Essentially, the same pattern as in Maharashtra was noted in the case of MTW also.

Essentially, the same patterns in yield distributions were noted in WMH (Figure 20) also as were noted in Figures 18 and 19. The yield distributions were leptokurtic under all the three possible weather conditions-bad, normal and best years. The measure of kurtosis dropped as we moved from a bad year distribution to a normal year and finally to the best year. The actual yield distribution for 2012-13 was closer to normal distribution and it lay between the distributions of a bad year and a normal year.

Variability in productivity across time, 2010-11 to 2012-13

The collection of data on yields of pearl millet achieved in 2010-11 and 2011-12 involved longer recall when compared with the data recorded for 2012-13. Figure 21 gives the distributions of grain yield achieved in 2010-11, 2011-12 and 2012-13 in Maharashtra. Since 2010-11 was the best of the three years,

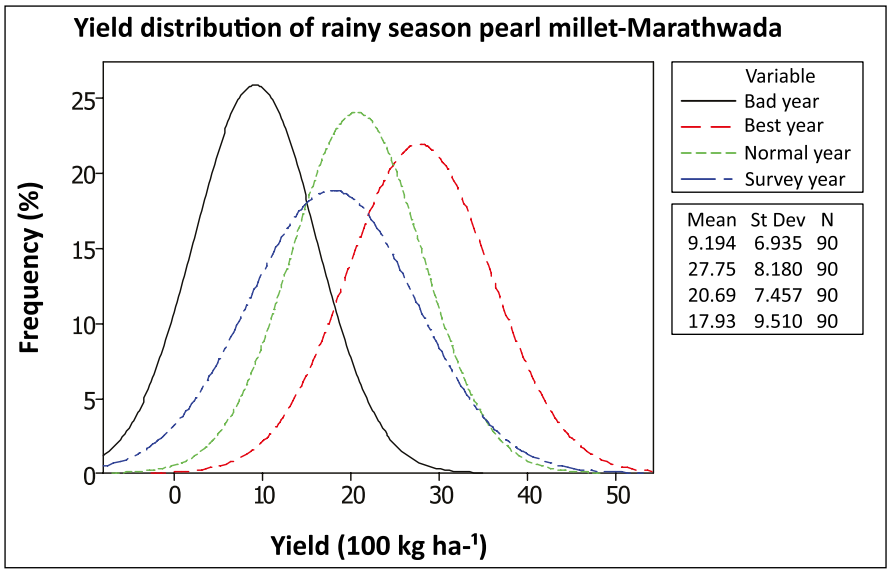

Figure 19. Yield distributions of improved cultivars in MTW region.

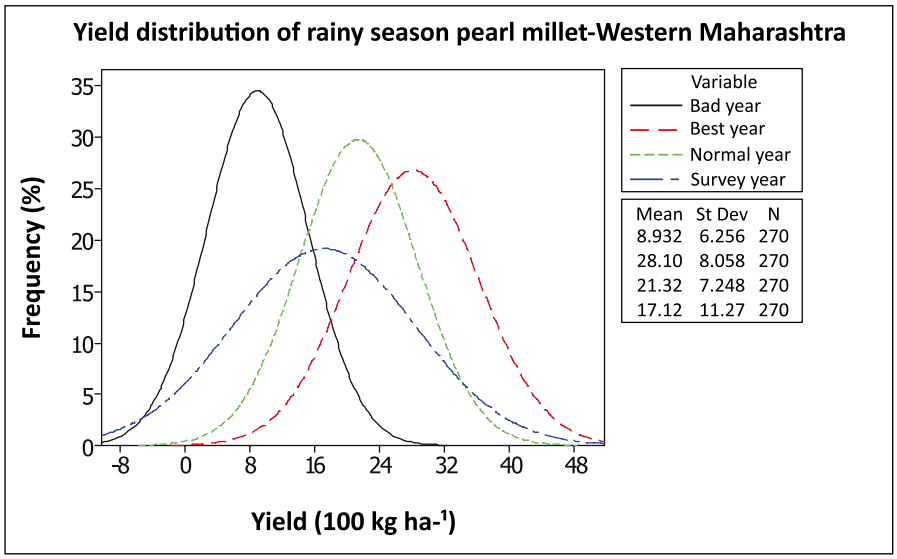

Figure 20. Yield distributions of improved cultivars in WMH region.

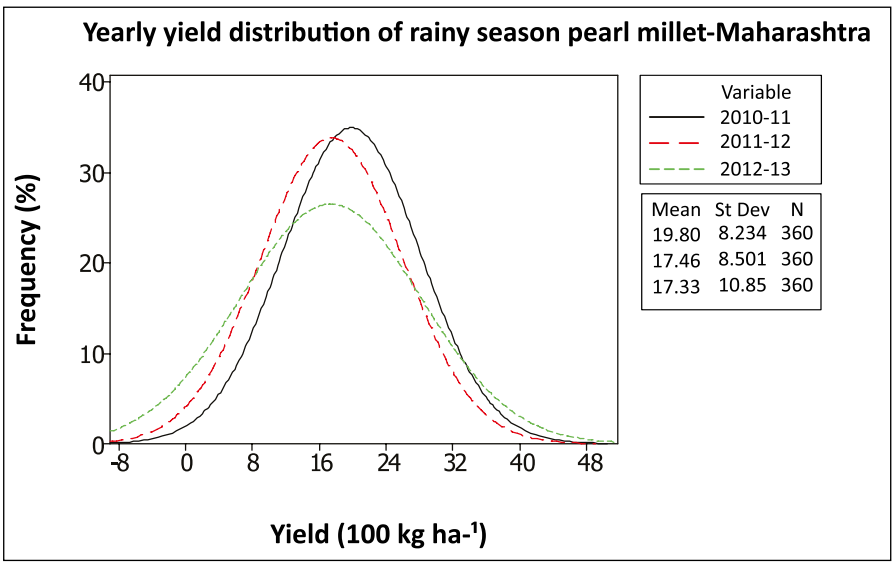

Figure 21. Grain yield distributions of pearl millet in Maharashtra, 2010-11 to 2012-13.

the yield distribution for that year was to the right of the other two distributions. Among the distributions for the three years, the distribution for 2012-13 was closer to normal than those for the other years. The other two were more leptokurtic because of a recall bias.

The distributions of pearl millet fodder in Maharashtra are depicted in Figure 22. In the case of fodder also, the distribution for 2010-11 was to the right of other two distributions. As in the case of grain, the distribution for 2012-13 was closer to normal when compared with those for the other two years. But, in general, the measure of kurtosis is higher in fodder yield distributions than in grain yield distributions.

Among the three year distributions for grain yield in MTW, the one for 2011-12 was the most leptokurtic one (Figure 23). The distribution for 2010-11 lay to the right of the other two distributions. The distribution for 2012-13 was closer to normal.

The patterns of grain yield distribution in case of WMH (Figure 24) were similar to the ones depicted in Figure 23 for MTW. The only difference was that the one for 2010-11 was the most leptokurtic in this case, although it did lie to the right of the distributions for the other two years. The distribution for 2012-13 was more bell-shaped, tending to normality, although it lay to the left of the distributions for the other two years.

The visual representation of the distributions of per hectare yields of major improved cultivars of pearl millet in Maharashtra is depicted in Figure 25. Of all the hybrids, Mahyco 204 had the best distribution.

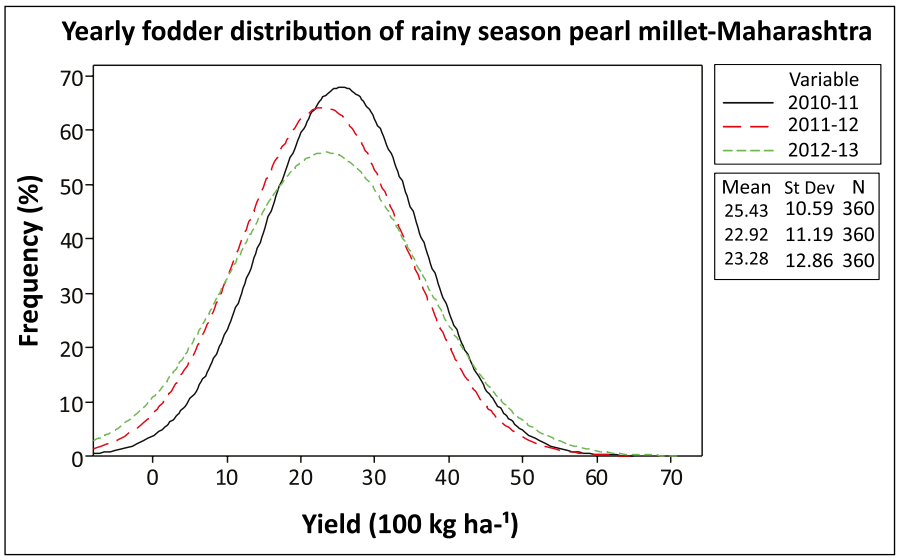

Figure 22. Fodder yield distributions of pearl millet in Maharashtra, 2010-11 to 2012-13.

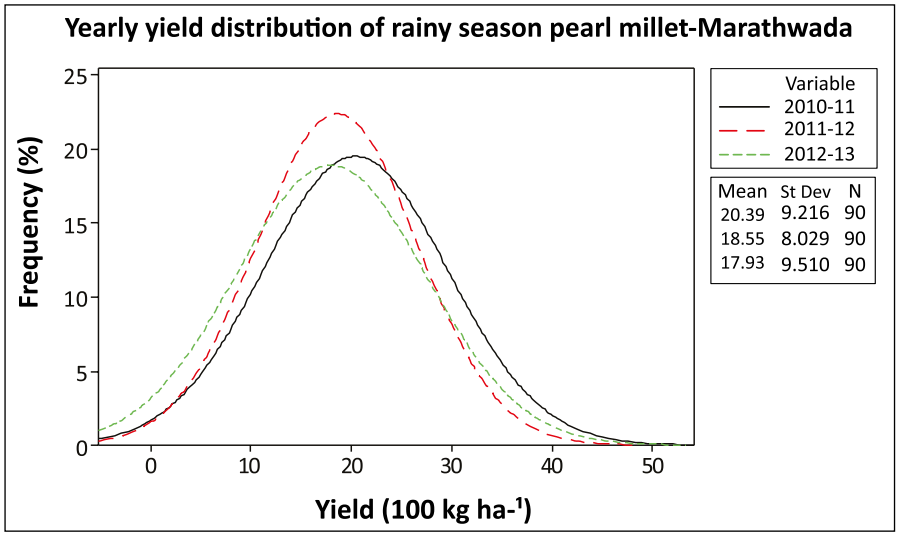

Figure 23. Distribution of pearl millet grain yield in MTW, 2010-11 to 2012-13.

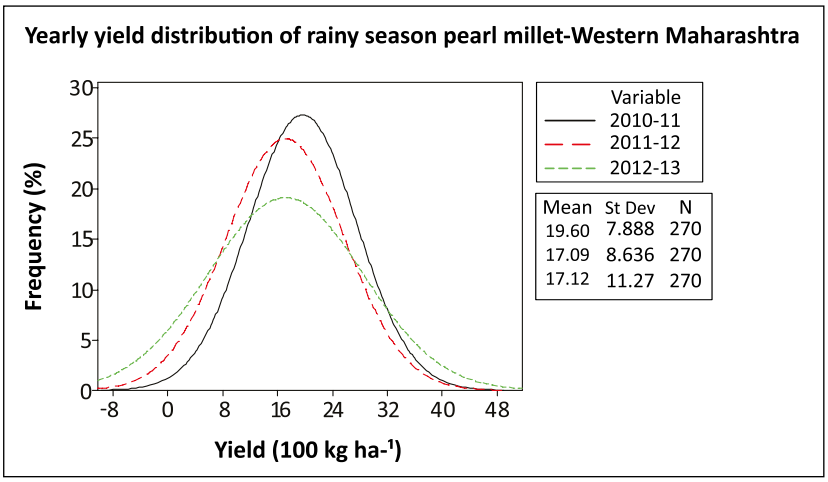

Figure 24. Distribution of pearl millet grain yield in WMH, 2010-11 to 2012-13.

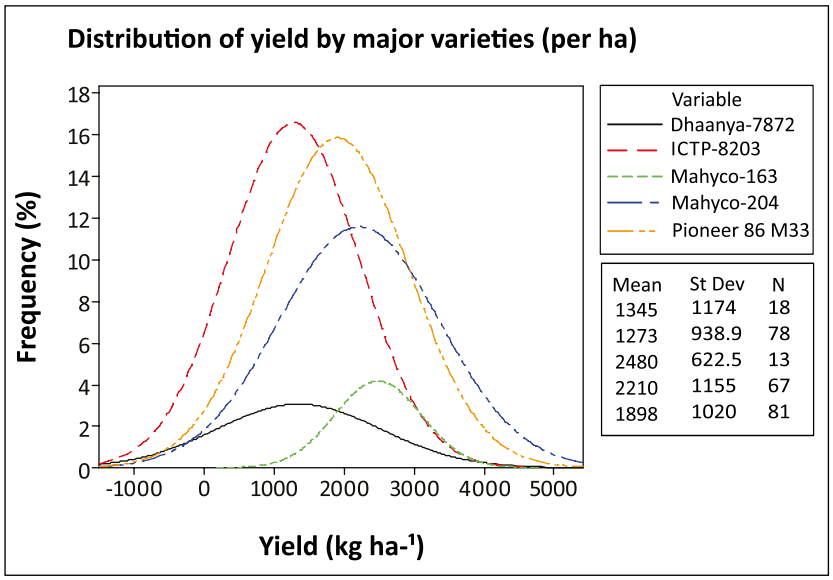

Figure 25. Yield distribution of major pearl millet cultivars in Maharashtra, 2012-13.

It followed normal distribution and some of the farmers recorded the best yields. Mahyco 163 reported the best mean yield of all, but it exhibited platykurtic distribution, perhaps because of less number of observations. Dhaanya 7872 also presented a platykurtic distribution and a wide diversity, with the highest standard deviation. It also had only 18 observations. Pioneer 86 M 33 also had an impressive distribution, next to Mahyco 204. But it had a high peak, making it leptokurtic. The composite variety, ICTP 8203, also showed a leptokurtic distribution and it lay to the left of all the hybrids, indicating its low yield potential.

6.2.4 Unit cost reduction (UCR) due to improved technology

During 2012-13, ICTP 8203 covered the highest percent area of pearl millet (Table 36). Although it was the oldest variety released, it is still covering more than one-fourth of the total pearl millet area of the sample. It is shorter in duration and can produce some yield even in the poorest soils. Being the only composite variety, its seed cost is lowest. Its bread (*bhakri*) quality is the best, with a slightly sweetish taste. Due to these reasons, it is still in contention, despite its low yield potential. Mahyco 204, was the second most popular variety, covering about 18% area. MLBH 308, which occupied 3.5% area, was also released prior to 2000, Mahyco 163, whose release year could not be ascertained precisely (but believed to be released prior to 2000), also covered 3.2% area. These four varieties, which were released prior to 2000, have stood the test of time and are together occupying about 52.3% area of pearl millet of the sample farmers even

Table 36. Major cultivars observed during 2012-13 HH survey.

Cultivar	Release Year	% area occupied
ICTP 8203	1988	27.6
Mahyco 163	-	3.2
Mahyco 204	1995	18.0
MLBH 308	1998	3.5
Pioneer 86 M 32	2002	6.5
Panchaganga 510	-	3.3
Pioneer 86 M 33	2009	14.6
Dhaanya 7872	2009	5.1
Nirmal 9	2001	2.1
GK 1044	-	2.9
Varun 666	-	1.4
MRB 2240	2010	1.2
B 2301	2007	1.1
MDBH 318	-	1.0

in 2012-13. All other ten hybrids released after 2000 together covered 39.2% of the area. Only Pioneer 86 M 33, which was marketed first in 2009, was the most popular among them, with a share of 14.6%. It was distantly followed by Pioneer 86 M 32, Dhaanya 7872, Panchaganga 510, GK 1044 and Nirmal 9. Each of these cultivars had an area share of more than 2%. The remaining four hybrids – Varun 666, MRB 2240, B 2301 and MDBH 318 – had shares ranging between 1.0% and 1.4% each. The remaining 8.5% pearl millet area was occupied by many other hybrids, each of which have small and insignificant shares.

The cultivars which figured in Table 36 are also listed in Table 37. The four variety/hybrids released before 2000 are assigned the value of 1, while the ten hybrids released after 2000 are assigned the value of 2. It is proposed to bundle the cultivars belonging to category 1 and also the relatively new cultivars belonging

Table 37. Categorization of pearl millet improved cultivars.

Cultivar	Release Year	Category
ICTP 8203	1988	1
Mahyco 163	-	1
Mahyco 204	1995	1
MLBH 308	1998	1
Pioneer 86 M 32	2002	2
Panchaganga 510	-	2
Pioneer 86 M 33	2009	2
Dhaanya 7872	2009	2
Nirmal 9	2001	2
GK 1044	-	2
Varun 666	-	2
MRB 2240	2010	2
B 2301	2007	2
MDBH 318	-	2

to category 2 separately, and assess the performance of these two categories of improved cultivars developed over a period of time.

The cost of cultivation of individual cultivars is summarized in Table 38. Of all the cultivars, Mahyco 163 performed the best with the highest yield, followed by Mahyco 204 and Pioneer 86 M 33 (all three yielded more than two tons per hectare). Consequently, the cost of production per ton of grain or fodder or grain (after deducting the fodder value from the total variable cost of production) were lower in the case of these varieties. The cost of production per ton of grain was lower than USD 150 (after adjusting for fodder value). Although Nirmal 9 yielded less, the cost of cultivation was lower in its case and, consequently, its cost of production was lower than USD 150 per ton of grain. Next to these four hybrids, Pioneer 86 M 32 and MLBH 308 were also able to keep the cost of production per ton of grain between USD 150 and USD 160. Panchaganga 510 and Dhaanya 7872 were also able to contain the cost of production below USD 200 per ton. When compared to all these hybrids, the composite variety ICTP 8203 recorded a unit cost of production greater than USD 200 per ton. Perhaps, it was grown in poor soils (as indicated by the lower fixed cost on account of less rental value of land) and that may be the other reason for highest unit cost of production.

The cost of cultivation and cost of production (USD per ton) of the cultivars released before 2000 and those released after 2000 are compared in Table 39. One fact has to be highlighted while considering these results. There were many varieties and hybrids released before 2000. Among them, the most successful ones are in cultivation even now. Some of the varieties released after 2000 are reaching to the ceiling level in the adoption stage. The total variable cost per ha has gone up slightly in the case of cultivar group released post-2000 as compared to the pre-2000 group. This is because of better management practices being followed by sample farmers in the case of new hybrids instead of old ones. However, productivity per ha (weighted based on adoption shares) has increased marginally (6%) in the case of new cultivars versus the pre-2000 released group. Similarly, the gross benefits per ha also increased by 13%. The translated UCR due to improved technology was estimated at USD 32.4 per ton between these groups for pearl millet grain production.

The four hybrids/varieties released before 2000, together occupied 52.3% of the pearl millet area during 2012-13 (see Table 40). The remaining 47.7% area was under all new varieties put together. But the five most important hybrids released after 2000 together covered 31.6% of the pearl millet area of the sample farmers in 2012-13. Other hybrids together accounted for the remaining 16.1% area. It was decided to confine the analysis to the more successful five hybrids released after 2000 as the other marginally successful ones are likely to fade out from the market. When the analysis is confined to the four successful varieties released before 2000, and the five successful hybrids released after 2000, the unit cost of production in case of the new varieties fell by USD 26.12 per ton of grain (after adjusting the cost of cultivation for the fodder value).

6.2.5 Quantification of *ex-post* research benefits

The research benefits due to the adoption of improved technology were estimated using the *ex-post* framework developed by Bantilan et al. (2013). The total production of pearl millet in the nine study districts added up to 0.774 million tons (Table 41). The production of pearl millet in the other districts of Maharashtra was 0.077 million tons. The consumption of pearl millet in the nine study districts was estimated at 0.154 million tons based on the estimates of per capita consumption in the rural and urban areas of these districts. The consumption in the rest of Maharashtra was estimated at 0.015 million tons. The remaining production of 0.683 million tons is expected to be consumed in the remaining parts of India. The farm gate price of pearl millet was taken as USD 238 per ton as reported by the publication of Directorate of Economics and Statistics. The elasticity of supply was assumed at 0.5, while the price elasticity of demand was assumed as -0.02. These assumptions were made based on the literature of supply and demand elasticity for coarse cereals in India. The research lag was taken as nine years ie, the time taken for a research project to develop hybrids either in the public or private sector. The adoption lag was taken as three years, ie, the time required for seed production, field trials and popularization

Table 38. Costs and returns from major cultivars.

Operation (USD per ha)	Pioneer 86 M 33 41 plots	Dhaanya 7872 10 plots	ICTP 8203 40 plots	Mahyco 163 11 plots	Mahyco 204 33 plots	MLBH 308 5 plots	Nirmal 9 3 plots	Panchaganga 510 4 plots	Pioneer 86 M 32 3 plots
Land preparation	52.8	51.1	53.0	51.7	52.7	54.8	41.9	49.4	48.6
Seed bed preparation	0.9	0.0	1.3	2.6	3.7	0.0	0.0	0.0	0.0
Compost/animal penning	21.5	51.5	21.7	7.4	12.7	0.0	30.7	38.2	0.0
Planting	34.4	27.2	31.3	31.4	33.7	24.3	30.0	31.4	30.7
Seed cost	14.4	13.6	20.1	14.1	14.8	13.7	13.5	13.5	17.9
Seed treatment	0.1	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
Fertilizer cost	53.0	34.9	37.9	50.0	53.4	43.8	19.7	43.7	55.4
Micro-nutrient	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0
Interculture	13.1	11.4	11.6	1.8	14.0	17.1	6.7	0.0	3.7
Weeding	47.1	31.2	35.3	53.3	48.2	43.2	41.9	34.4	39.7
Plant protection	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Irrigation	9.8	0.0	5.8	5.7	12.1	0.0	0.0	16.8	0.0
Watching	0.5	0.0	1.2	5.7	0.4	0.0	0.0	0.0	0.0
Harvesting	60.6	36.3	49.9	59.4	53.8	51.4	44.1	47.1	36.7
Threshing	46.0	24.9	32.0	64.2	57.6	37.4	39.7	34.4	33.1
Marketing	9.1	5.7	4.9	11.5	11.5	7.3	5.6	6.9	5.9
Total Variable Cost (TVC)	363.4	287.8	306.7	359.0	368.6	292.9	273.7	315.7	271.7
Fixed Cost/acre (FC)	180.4	202.7	131.1	221.0	212.4	145.1	192.2	202.6	150.3
Total Cost (TC)	543.8	490.5	437.8	580.0	580.9	438.0	465.9	518.3	421.9
Grain yield (kg ha^{-1})	2141.5	1299.2	1163.4	2694.8	2410.7	1580.8	1563.5	1790.8	1563.5
Price (USD/ton)	236.4	236.4	236.4	236.4	236.4	163.6	236.4	236.4	236.4
By-products(kg)	2960	1480	1730	3460	3210	2470	2470	1730	1980
By-products Price (USD/100 kg)	1.8	2.2	2.7	1.1	1.4	1.8	2.4	1.6	1.6
Gross Returns	560.1	339.4	321.5	674.0	614.2	303.6	429.3	450.9	400.8
COP/ton (VC)-Grain	169.7	221.5	263.7	133.2	152.9	185.3	175.1	176.3	173.7
COP/ton (VC)-Stover	122.6	194.2	177.4	103.8	114.8	118.6	110.8	182.6	137.5
COP/ton (VC)-Grain*	144.5	196.6	223.7	119.4	134.5	156.9	136.9	160.9	153.8

*Variable cost after deducting the fodder value generated per ha

Table 39. Relative performance of old and new category cultivars.

	Old cultivars (before 2000)	New cultivars (After 2000)
Activity	89 plots	61 plots
Land preparation	52.8	51.6
Seed bed preparation	2.2	0.6
Compost/animal penning	15.4	26.9
Planting	31.8	32.6
Seed cost	17.0	14.6
Seed treatment	0.0	0.0
Fertilizer cost	32.6	47.9
Micro-nutrient	0.0	0.0
Interculture	11.6	11.2
Weeding	42.8	43.0
Plant protection	0.0	0.0
Irrigation	7.8	7.7
Watching	1.4	0.4
Harvesting	52.6	53.7
Threshing	45.8	40.9
Marketing	8.4	8.1
Total Variable Cost (TVC)	322.2	339.2
Fixed cost/ha	173.1	184.6
Total Cost (TC)	495.3	523.8
Grain yield (kg ha^{-1})	1714.4**	1812.0**
Price (USD/ton)	218.2	236.4
By-Product (kg ha^{-1})	2470	2470
Price (USD/100 kg)	2.0	2.0
Gross Returns/ha	423.48	477.76
COP/ton (VC) for grain	212.3**	179.9**

Unit: USD per ha ** weighted average estimates

of the hybrids. Thus, the total lag between research and early adoption was figured out as 12 years. Similarly, it was assumed that it would take nine more years from early adoption to the time the hybrid would reach the ceiling level of adoption of 100%. Thus, the total lag between the start of research and the hybrid reaching its ceiling level of adoption added up to 21 years. As already worked out, the UCR due to the technical change was to the extent of USD 26.12 per ton. These parameters from data, along with considered assumptions, were used to estimate the total benefits arising from research.

Table 40. Estimation of UCR due to improved pearl millet technology.

Cultivar	Release year	Category	Actual adoption (% Area)	COP/ton over VC for grain (USD)	COP/ton over VC for stover (USD)	COP/ton after subtracting fodder value (USD)	Weighted adoption rate	Weighted grain	Weighted stover	Weighted grain*
ICTP 8203	1988	1	27.6	263.7	177.4	223.7	52.8	139.2	93.6	118.1
Mahyco 163	-	1	3.2	133.2	103.8	119.4	6.1	8.1	6.4	7.3
Mahyco 204	1995	1	18.0	152.9	114.8	134.5	34.4	52.6	39.5	46.3
MLBH 308	1998	1	3.5	185.3	118.6	156.9	6.7	12.4	7.9	10.5
			52.3							
Pioneer 86 M 32	2002	2	6.5	173.7	137.5	153.8	20.6	35.7	28.3	31.6
Panchaganga 510	-	2	3.3	176.3	182.6	160.9	10.4	18.4	19.1	16.8
Pioneer 86 M 33	2009	2	14.6	169.7	122.6	144.5	46.2	78.4	56.6	66.8
Dhaanya 7872	2009	2	5.1	221.5	194.2	196.6	16.1	35.7	31.3	31.7
Nirmal 9	2001	2	2.1	175.1	110.8	136.9	6.6	11.6	7.4	9.1
			31.6							
							Category-1	212.3	147.4	182.1
							Category-2	179.9	142.7	156.0
							UCR	32.40	4.71	26.12

***** after adjusting the fodder value per hectare
COP: Cost of production
VC: Variable costs

Table 41. Parameters used in quantification of research benefits.

Parameter	Ahmednagar	Aurangabad	Beed	Dhule	Jalgaon	Nashik	Pune	Sangli	Satara	Rest of MH	Rest of India
Pearl millet production ('000 tons)	131.5	117.2	104.7	106.8	39.8	178.9	34.6	27.2	32.9	76.7	0.0
Pearl millet consumption ('000 tons)	26.3	23.4	20.9	21.4	8.0	35.8	6.9	5.4	6.6	15.3	680.3
Farm gate price (USD/ton)#	238	238	238	238	238	238	238	238	238	238	238
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
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
Research lag (years)	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
Initial adoption lag (years)**	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
Ceiling level of adoption (Proportion)	1	1	1	1	1	1	1	1	1	1	1
UCR (USD/ton)	26.12	26.12	26.12	26.12	26.12	26.12	26.12	26.12	26.12	26.12	26.12

* Both public and private sectors have started research since 1993 (Improved cultivars were released-in 2002).
* * From release of cultivars to initial adoption
Based on Maharashtra Agricultural Statistics, 2012-13

In the model, both the production and consumption were equated at 850.3 thousand tons (Table 42). The total welfare change was estimated at USD 103.3 million. The share of the producers was only 29% due to the low price elasticity of demand assumed in the model. Thus, the total producer surplus was estimated at USD 29.5 million. Since the supply elasticity assumed was far higher than the demand elasticity, the consumers could appropriate the remaining 71% of the total welfare benefits. The consumer surplus was estimated at USD 73.8 million. The benefits that accrued to the adopters were estimated at USD 29.6 million. An insignificant proportion of non-adopters has incurred a loss of USD -0.1 million. The net benefit to the producers was USD 29.5 million.

Out of the total welfare benefits of USD 103.3 million estimated from the model, only 43.3% accrued to the farmers and consumers in Maharashtra (Table 43). The remaining 56.7% of the benefits accrued to the consumers of pearl millet in the rest of India who consumed the produce from Maharashtra. The total benefits accrued to MTW region were estimated at USD 11.6 million. Producers gained USD 7.7 million, while the consumers from the region accounted for the remaining USD 4.0 million. In WMH region, the total benefits were estimated at USD 29.0 million. Out of this, USD 19.1 million accrued to the farmers, while the remaining USD 9.8 million accrued to the consumers. In this region, there was a small minority of farmers who kept staying with the local varieties and they incurred a loss of USD 0.1 million. The adopters benefitted to the extent of USD 19.2 million. The net producer surplus added up to USD 19.1 million. In the rest of Maharashtra, the total benefits were estimated at USD 4.1 million. Producers could appropriate USD 2.7 million, while the consumers benefitted to the tune of USD 1.4 million. Since the consumers in Maharashtra were estimated to have consumed only 20% of the production of pearl millet in the state, much of the consumer surplus was appropriated by consumers in other parts of the country.

The total welfare change due to technical improvements was estimated at USD 103.3 million (Table 44). The producer surplus due to adopters was USD 29.6 million. But the losses incurred by non-adopters were estimated at USD 0.1 million. The net producer surplus was estimated at USD 29.5 million. The consumer

Table 42. Direct welfare estimates due to improved pearl millet technology in Maharashtra.

Welfare benefits	Value
Total Production ('000 tons)	850.3
Consumption at farm household level ('000 tons)	850.3
Total welfare change	103.3[#]
Producer surplus	29.5[#]
Consumer surplus	73.8[#]
Adopters	29.6[#]
Non-adopters	-0.1[#]

[#] million USD

Table 43. Welfare benefits across regions and Maharashtra.

Type	MH Total	MTW[#]	WMH[#]	Rest of MH[@]	Rest of India
Total research benefits	103.3	11.6	29.0	4.1	58.7
Producer gains	29.5	7.7	19.1	2.7	0.0
Consumers gains	73.8	4.0	9.8	1.4	58.7
Adopters benefits	29.6	7.7	19.2	2.7	0.0
Non-adopters losses	-0.1	0.0	-0.1	0.0	0.0

Unit = Million USD

[#] includes the sample districts (see appendix -1 for more details)

@ includes the non-sampled 14 pearl millet growing districts in MH

surplus was estimated at USD 73.8 million. It is true for a majority of agricultural products, for which the price elasticity of demand was quite low. Since the supply elasticity is much higher for these than the demand elasticity, much of the welfare benefits due to agricultural technology innovations reach the consumers. The district-wise breakup of welfare benefits are furnished in Appendix 5.

Table 44. Disaggregation of welfare benefits.

Type	Total MH benefits (million USD)	Benefits due to non-adopters (million USD)	Benefits due to adopters (million USD)
Total welfare change	103.3	-0.1	103.4
Producer surplus	29.5	-0.1	29.6
Consumer surplus	73.8	0.0	73.8

6.2.6 Competitiveness of pearl millet in Maharashtra

Table 45 summarizes the competitiveness of pearl millet crop across two regions and the state as a whole. The competitiveness of pearl millet was assessed in comparison with other major rainy season crops existed in those regions. Cotton, maize and soybean are the major competing crops for pearl millet among the two regions of the study. Pearl millet could not recover total costs per hectare while hardly earning some marginal returns after total variable costs (see Table 45). The complete breakup of cost of cultivation of rainy and postrainy season crops are summarized in Appendix 6.

Table 45. Competitiveness of pearl millet across regions.

Crop name	TVC/ha	TC/ha	GR/ha	NR over TC	NR over VC
MTW region					
Pearl millet	371.6	501.1	457.5	-43.6	85.9
Cotton	686.0	835.4	1154.8	319.4	468.8
Soybean	578.2	709.8	502.9	-206.9	-75.3
Maize	577.0	770.7	1483.6	712.9	906.6
WMH region					
Pearl millet	329.1	514.7	475.3	-39.4	146.2
Cotton	511.4	696.0	817.3	121.4	306.0
Maize	587.1	820.4	1194.7	374.3	607.6
Soybean	446.3	689.3	815.3	126.0	369.0
Groundnut	496.8	657.0	880.3	223.3	383.5
Pooled Maharashtra					
Pearl millet	339.7	511.5	471.0	-40.5	131.3
Cotton	602.5	768.7	974.2	205.5	371.7
Maize	585.2	811.1	1247.4	436.3	662.2
Soybean	490.2	696.1	715.2	19.1	225.0

Unit : USD per ha
TVC: Total Variable Costs
TC : Total Costs
GR : Gross Returns
NR: Net Returns

6.3 Facilitating factors

The drivers of pearl millet technology adoption across regions in the state, pearl millet farmers' access to 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

Farmers get their information about technology from different sources. Farmers' clubs are the most important sources with the highest membership, acquiring and sharing information with farmers and have credibility. They serve as information sources for more than one-third of the sample farmers (Table 46). Friends are also important sources with maximum membership, but they lack credibility and many do not rely on them as a source of accurate information about technology. Relatives are next only to friends in membership and reach, but they too suffer from low credibility. Krishimitra groups, other self-help groups and panchayats have relatively lower reach but have good credibility. Cooperatives and caste groups are the other networks, but they have less membership and reach.

6.3.2 Access to credit

In MTW, the average household borrowed USD 728 (Table 47) of which about 70% was borrowed for agriculture. About 11% of it was for the purpose of purchasing machinery and the remaining 19% was for other purposes. The interest rates on the loans ranged between 2% and 18% per year. Nearly 68% of the loans taken were still outstanding against the farmers. In the case of WMH, the average amount borrowed per household was USD 661. About 76% of it was taken for agricultural purposes, 21% was taken for the purchase of machinery, and 3% was for the purchase of livestock. The interest rate on the loans taken ranged between 2% to 14% per year. About 69% of the loans taken in WMH are still outstanding against the borrowers. The weighted average amount borrowed in the sample was USD 678 and 68% of it is still unpaid by the farmers.

The dependence on informal sources of credit was minimal in both the regions (Table 48). In MTW, it was as low as USD 16, while it was USD 58 in WMH. Compared to the amount borrowed from institutional sources, these amounts are quite in-significant. The interest rate on the informal sources of credit was also moderate, ranging between 4% and 12%. In the pooled sample, the amount borrowed from informal sources was USD 48 and the amount outstanding was only USD 11 per household. Only 23% of the amount borrowed from informal sources remains unpaid by the farmers.

6.3.3 Perceptions about technology and sustainability issues

A large percentage of sample farmers in both the regions felt that they were benefiting considerably from the improved production technology in the case of pearl millet (Table 49). The respondents believed that the grain yield had increased by 18% and that the fodder yield had increased by 14% over a period of one

Table 46. Different informal networks as primary sources of information.

Network type	% HH member in this network	% HH using this network to share/acquire information	% HH believe in this network
SHGs	15.8	16.9	12.2
Krishimitra	15.3	17.2	15.6
Cooperative	2.5	3.1	1.9
Farmer club	38.1	39.4	37.5
Caste group	0.8	0.8	0.8
Relative	31.7	26.1	13.1
Friends	41.4	42.8	16.4
Panchayat	11.1	22.5	11.1

Table 47. Formal sources of credit during 2012-13.

	Pooled (N=360)				
Particulars	Agriculture	Livestock	Machinery	Others	Pooled
Amount (USD per HH)	501.60	15.66	124.55	35.86	677.66
Avg. Interest rate (range)	2-14%	9.14%	4-18%	7-12%	-
Outstanding amount (USD per HH)	302.40	11.11	114.32	36.26	464.10
			MTW (N=90)		
Amount (USD per HH)	505.45	-	80.81	141.41	727.67
Avg. Interest rate (range)	2-13%	-	18%	12%	-
Outstanding amount (USD per HH)	290.88		60.61	143.84	495.33
			WMH (N=270)		
Amount (USD per HH)	500.31	20.88	139.12	0.67	660.98
Avg. Interest rate (range)	2-14%	9-14%	4-12%	7%	-
Outstanding amount (USD per HH)	306.24	14.81	132.23	0.40	453.68

Table 48. Informal sources of credit per HH during 2012-13.

	Pooled (N=360)		
Particulars	Agriculture	Machinery	Pooled
Amount (USD per HH)	47.73	-	47.73
Avg. Interest rate (range)	4-12%	-	-
Outstanding amount (USD per HH)	8.96	-	8.96
		MTW (N=90)	
Amount (USD per HH)	16.16	-	16.16
Avg. Interest rate (range)	6%	-	-
Outstanding amount (USD per HH)	2.02	-	2.02
		WMH (N=270)	
Amount (USD per HH)	58.25	-	58.25
Avg. Interest rate (range)	4-12%	-	-
Outstanding amount (USD per HH)	11.28	-	11.28

Table 49. Farm-level benefits of pearl millet technology compared to a decade ago.

	Benefits in		
Type of benefit	MTW (N=90)	WMH (N=270)	Pooled (N=360)
Percentage increase in grain yield/ha	16.93 (80)	17.83 (181)	17.56 (261)
Percentage increase in fodder yield/ha	12.84 (82)	14.79 (196)	14.22 (278)
% overall household welfare position increased	8.40 (25)	10.95 (97)	10.43 (122)
Better grain quality (Yes)	(81)	(231)	(312)
Better fodder quality (Yes)	(79)	(211)	(290)
Reduced duration leading to higher cropping intensity (Yes)	(81)	(192)	(273)
Resistance to diseases (Downy mildew)*	323.40 (86)	309.28 (234)	313.07 (320)
Tolerance to drought*	127.71 (54)	87.62 (133)	99.20 (187)
Reduction in pearl millet area for meeting family needs due to higher yield (% area reduced per HH)	47.88 (26)	46.35 (55)	46.84 (48)

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

decade. The sample farmers saw a 10% increase in their overall welfare position. About 87% believed that the grain quality has improved and 81% noticed an improvement in the fodder quality as well. More than three-fourths of the farmers felt that the improved varieties have reduced the duration of the crop. Almost 90% of the sample farmers also felt that the resistance to diseases (particularly downy mildew) has also improved. A little more than one-half of the sample farmers credited the new varieties with better resistance to drought. Nearly one-half of the sample farmers felt that they were able to reduce the pearl millet area and still meet their family's needs for grain and fodder. They felt that they could reduce the area under pearl millet area by one-half and still meet their requirements. With regard to all these parameters, the perceived benefits were relatively higher in WMH than in MTW.

But the indicators of sustainability show that agriculture, in general, is heading more towards unsustainability (Table 50). About one-third of the sample farmers felt that livestock population is on the decline. About one-fifth felt that the livestock population has increased and the remaining opined that the livestock population has remained constant. Interestingly, there was a feeling that fodder availability is on the rise. 42% felt that there was no change in the availability of fodder. About one-third believed that fodder availability is decreasing, while about one-fourth felt the opposite. About 64% held that the area under green manure crops remained constant. More than one-third of the farmers felt that the area under green manure crops is declining, while barely 2% indicated that it is increasing. With regard to area allocated to food crops, one-half of the sample felt that there was no change. But 40% of the sample farmers stated that the area under food crops is decreasing, while the remaining 10% felt the contrary. More than two-thirds of the sample population acknowledged that there was no change in the size of holding. But 29% were of the opinion that it has decreased and only 3% felt that it has increased. 62% of the farmers indicated that there was no change in the cropping intensity; whereas 29% believed that the land use intensity has decreased. Only 9% mentioned that land use intensity has increased. 64% of the respondents opined that the use of legumes in crop rotations has not changed; 23% felt that legumes are being used less frequently in crop rotations than before, and the remaining 13% indicated that the use of legumes in crop rotation has increased.

Interestingly, farmers felt positive about the use of farmyard manure (FYM). One-third of the farmers felt that there was no change in the use of FYM, whereas 55% indicated that the use of FYM has increased, while the remaining 12% felt that it has decreased. 53% opined that the public and private investments on soil conservation remained unchanged. As the number of livestock did not increase, the composition might have changed in favor of dairy animals which are well fed and, hence, yield more FYM. Another reason could be that farmers are shifting to the use of gas and gobar (made from dung) to cook their food, which might have led to the increase in FYM available for manuring. But 29% saw a spurt in FYM, while the remaining 18% perceived that they have decreased. It is also gratifying to note that 58% believed that soil loss due to erosion has decreased; only 16% believed that the soil loss due to erosion has increased, while the remaining 26% saw no change. With respect to soil fertility, 56% felt that it has improved; 22% saw no change, while the remaining 22% perceived a decline in the fertility status. More than three-fourths of the farmers said that they are now using more inorganic fertilizers that supply major nutrients, such as nitrogen, phosphorous and potash; 21% saw no change in the use of inorganic fertilizers, while a small minority of 3% indicated that the use of inorganic fertilizers has declined. 77% did not see any change in the use of micronutrients, such as zinc, manganese, iron, boron, etc; 12% felt that it has increased and the remaining 11% believed that it has decreased. About 55% felt no change in the frequency of soil testing, while one-fourth felt that it has increased and the remaining one-fifth noted that it has decreased.

About one-half of the sample saw no change in the use of plant protection chemicals; 30% felt that use of chemicals has increased, while the remaining 20% believed that it has decreased. A majority (93%) of the farmers responded that the expenditure on farm mechanization has increased, while 6% did not perceive any change. Only 1% of the farmers felt that the expenditure on farm machinery has decreased.

Table 50. Perceptions of sample farmers about agricultural sustainability.

	Pooled (% of HH)		
Indicator	Increased	Constant	Decreased
Livestock population (No. per HH)	20.0	46.1	33.9
Availability of fodder/grazing pastures	32.2	42.2	25.6
Area under green manure crops	1.7	64.2	34.2
Land allocation for food crops (acres)	9.7	50.3	40.0
Average landholding size of farm (acres)	3.1	68.3	28.6
Land-use intensity (no. of crops per year)	28.9	61.7	9.4
Use of legumes in crop-rotations/inter-cropping	13.3	64.2	22.5
FYM/other organic matter application rate (Qtl/acre/year)	55.3	32.5	12.2
Soil and water conservation investments per acre (private and public)	28.9	53.1	18.1
Soil loss due to erosion	15.8	26.4	57.8
Soil fertility status (organic carbon and NPK levels)	56.1	21.9	21.9
In-organic fertilizers (N, P, K – application rate)	76.4	20.6	3.1
Micro-nutrient application (kg/acre)	11.9	77.2	10.8
Frequency of soil testing and use of fertilizers based on recommendations	25.0	54.7	20.3
Expenditure on plant protection chemicals (Rs/acre)	30.0	49.4	20.6
Expenditure on farm mechanization (Rs/acre)	92.5	6.4	1.1

I-Increased; C- Constant; D- Decreased

7. Summary and conclusions

Pearl millet is a very important food crop in areas with low rainfall and shallow soils. Being shorter in duration, it is the most drought-tolerant cereal grown in the arid and semi-arid regions of the country. Rajasthan, Maharashtra, Uttar Pradesh, Gujarat and Haryana are the five most important states for pearl millet, accounting for 93% of area and production in the country. Both the private and public sector companies made use of parent materials from ICRISAT and developed a number of hybrid varieties suited for Maharashtra and are marketing them. This has widened the choice set of varieties and hybrids accessible to pearl millet farmers in Maharashtra. As their coverage was nearly universal, it was felt appropriate to assess the adoption and impact of improved varieties and hybrids on the crop yields and quantify the welfare benefits on farmers and consumers of pearl millet. For quantification of research benefits, the *ex-post* model developed by Bantilan et al. (2013) was used. The parameters on which data are collected or estimated from primary surveys for calculating the research benefits. The household study focused on nine major pearl millet growing districts in Maharashtra, as they together accounted for 90% share in area and 91% share in production. A sample of 20 *tehsils* was chosen from the areas in these districts where pearl millet cultivation was highly concentrated.

Pearl millet sample characteristics

The sample farmers were middle aged, with 25 years of farming and pearl millet cultivation experience. The households were invariably male headed with a lone exception. The average years of schooling of the household head was 7.5 years. The average family size was 5 in WMH and 5.5 in MTW. The main occupation of most of the households was farming, with livestock rearing as the supplementary one. The average size of ownership holding was 2.19 ha in WMH sample. The sample farmers possessed a high net worth, with an average asset value of USD 82,760 per household, out of which land value alone accounted for USD 71,950 per household. The liabilities were relatively insignificant. The per capita income of the

sample households was estimated at USD 2.80 per day. The average annual household expenditure was USD 2798, which translated in to a daily income of USD 7.67 per family and USD 1.48 per capita per day. About 30% of the pearl millet grain produced was consumed by the households. About 13% was kept in store for future needs and the remaining 57% was sold in the market. The pearl millet fodder was fed to the livestock.

Extent of adoption pearl millet improved cultivars

During the latest three years (2010-11 to 2012-13), ICTP 8203 was cultivated in 27.6% of the pearl millet area of the sample farmers. It was followed by Mahyco 204 (18%), Pioneer 86 M 33 (14.6%), Pioneer 86 M 32 (6.5%), Dhaanya 7872 (5.1%), MLBH 308 (3.5%), Panchaganga 510 (3.3%), Mahyco 163 (3.2%), GK 1044 (2.9%), Nirmal 9 (2.1%) and Varun 666 (1.4%). All other hybrid/varieties of pearl millet in the market accounted for the remaining 11.8%. The community surveys estimated that modern varieties covered 99.6%, leaving the remaining 0.4% to local varieties. But household surveys estimated the field situation precisely and are worth taking up. The average adoption lag observed among major pearl millet improved cultivars was between 6 and 9 years.

Yield perceptions

Sample farmers perceived that pearl millet would yield about 2100 kg of grain and 2700 kg of straw per hectare in a normal year. In a bad year, the yields would drop down to only 900 kg of grain and 1300 kg of straw per hectare. The best year yields observed were 2800 kg of grain and 3500 kg of straw per hectare. Among the three latest years for which data were collected, 2010-11 saw the best yields of 2000 kg of grain and 2500 kg of fodder per hectare.

UCR due to improved technology

Any successful technology is expected to result in the reduction of unit cost of production. The varieties and hybrids released or marketed prior to 2000 were grouped as category 1. Out of the many varieties and hybrids released/marketed prior to 2000 four (ICTP-8203, Mahyco-163, Mahyco-204 and MLBH-308) have survived till date and are occupying about 52.3% of the total area under pearl millet amongst the sample farmers. The 10 hybrids released/marketed after 2000 accounted for the remaining 47.7% area and were categorized as category 2. It is necessary to know whether a technology change occurred over these two distinct periods. The weighted average cost of production for the four pre-2000 hybrids/varieties was USD 182 per ton, while that of the post-2000 hybrids was USD 156 per ton, implying that there was a technological shift between these two periods and that it reduced the unit cost of production by USD 26 per ton.

Accrued welfare benefits

The total welfare change on account of the technological change was estimated to be USD 103.3 million between 1993 and 2022, but producers could receive only a share of USD 29.5 million out of that. The remaining USD 73.8 million was received by the consumers, and of that a larger share accrued to the consumers outside Maharashtra. In MTW region, pearl millet farmers profited to an extent of USD 7.7 million, while consumers could appropriate a benefit of USD 4.0 million. In the WMH region, which had a three-fourth share in the sample farmers, the benefits were higher at USD 19.1 million to farmers and USD 9.8 million to consumers.

Sustainability of pearl millet systems

Most of the sample farmers perceived an increase in grain and fodder yields of pearl millet as well as improvements in their quality. They also perceived that crop duration has decreased and that resistance to pests, diseases and drought has also improved in the new hybrids. They also felt that the use of FYM and other organic materials has improved, raising the soil fertility status. Yet, the expenditure on fertilizers and farm machinery has increased. They felt that soil loss due to erosion has decreased. With respect to all other parameters of sustainability, the reactions were mixed, with a large proportion of the sample rating no change in them.

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Appendix

Appendix 1

Table A1. Pearl millet cultivating regions in Maharashtra.

S.no	District	Region
1	Aurangabad	MTW
2	Beed	MTW
3	Ahmednagar	WMH
4	Dhule	WMH
5	Jalgaon	WMH
6	Nashik	WMH
7	Pune	WMH
8	Sangli	WMH
9	Satara	WMH

Appendix 2

Table A2. Sampling framework for the study.

District	Mandal	Mean area	Cul. total	Cul. adj	Add random value	Selection
Ahmednagar	Sangamner	45167.4	45167.4	0.886577	1.536577	1
Ahmednagar	Pathardi	32703	77870.4	1.528495	2.178495	1
Ahmednagar	Shevgaon	17381	133932	2.628911	3.278911	1
Ahmednagar	Rahuri	8261.4	173725.6	3.410008	4.060008	1
Aurangabad	Aurangabad	17523.6	223117.8	4.379512	5.029512	1
Aurangabad	Gangapur	11670.6	276082.4	5.419138	6.069138	1
Beed	Patoda	19852.6	338722.6	6.648684	7.298684	1
Beed	Majalgaon	16460.8	374958	7.359938	8.009938	1
Beed	Parali	8798.4	430325	8.44672	9.09672	1
Dhule	Sakri	39154.2	476394.8	9.35101	10.00101	1
Dhule	Sindkheda	25889.8	534949.4	10.50036	11.15036	1
Jalgaon	Parola	6104.8	579608.6	11.37696	12.02696	1
Nashik	Malegaon	37056.6	664396.2	13.04123	13.69123	1
Nashik	Sinnar	33342.8	697739	13.69571	14.34571	1
Nashik	Baglan (Satana)	29781	759069.4	14.89955	15.54955	1
Nashik	Chandwad	27562.6	786632	15.44056	16.09056	1
Pune	Shirur	16556.2	846665.2	16.61894	17.26894	1
Pune	Purandhar	8743.6	884544	17.36245	18.01245	1
Sangli	Kavathe-Mahankal	10162	937248.4	18.39697	19.04697	1
Satara	Man	19048.6	1001198	19.65222	20.30222	1

Random number used: 0.65

Appendix 3. Photographs of major pearl millet improved cultivars in Maharashtra

Appendix 4. Minimum dataset details and assumptions

Research lag (years)

This very important parameter was estimated via detailed discussions with research groups and careful reviewing 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.

UCR

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 rate: The 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 costs estimates for all improved cultivars.

Appendix 5

Table A3. Breakup of welfare benefits in Maharashtra

Parameter (Million USD)	MH	Ahmednagar	Aurangabad	Beed	Dhule	Jalgaon	Nashik	Pune	Sangli	Satara
Total research benefits	103.3	6.9	6.1	5.5	5.6	2.1	9.4	1.8	1.3	1.7
Producer gain	29.5	4.6	4.0	3.7	3.7	1.4	6.3	1.2	0.8	1.2
Consumers gain	73.8	2.3	2.1	1.9	1.9	0.7	3.2	0.6	0.5	0.6
Adopters benefits	29.6	4.6	4.0	3.7	3.7	1.4	6.3	1.2	0.9	1.2
Non-adopters losses	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	0.0

Parameter (Million USD)	MH	Rest of MH	Rest of India
Total research benefits	103.3	4.1	58.7
Producer gain	29.5	2.7	0.0
Consumers gain	73.8	1.4	58.7
Adopters benefits	29.6	2.7	0.0
Non-adopters losses	-0.1	0.0	0.0

Appendix 6

Competitiveness of pearl millet in Maharashtra

The comparative economics of pearl millet in MTW region in 2012-13 are presented in the first column of Table A4. The major items of cost of cultivation of pearl millet were land preparation, weeding, fertilizer cost, harvesting and threshing. The total variable cost added up to USD 371.6 per hectare. Fixed costs worked out to be USD 129.5 per hectare, raising the total cost of production to USD 501.1 per hectare. But the gross returns from pearl millet were only USD 457.5 per hectare, implying a net loss of USD 43.6 per hectare. But since only poor quality land is assigned to pearl millet, it is gratifying to learn that all the variable costs are recovered and that there is a surplus of USD 85.9 per hectare over the variable costs. As all the costs are not recovered, the benefit/cost ratio worked out to only 0.91 in 2012-13, which has been a sub-normal year from the point of view of rainfall and other climatic parameters. The economics of cotton cultivation are presented in the second column of the table. It is planted in better quality land (as reflected in the higher fixed costs due to higher rental value of land) and its variable costs were higher at USD 686 due to more intensive use of inputs. Although the total cost of cultivation was as high as USD 835.4 per hectare, the gross returns were much higher at USD 1154.8 per hectare, leaving a surplus of

Table A4. Costs and returns of rainy season crops in MTW region.

Activity (USD per ha)	Pearl millet 44 plots	Cotton 34 plots	Maize 10 plots	Soybean 5 plots
Land preparation	55.7	59.7	53.8	59.3
Seed bed preparation	1.9	26.2	16.7	22.4
Compost/animal penning	23.2	49.3	0.0	145.5
Planting	31.6	32.2	24.9	34.1
Seed cost	15.4	73.1	66.6	75.4
Seed treatment	0.0	0.0	0.0	0.0
Fertilizer cost	55.1	109.3	72.9	72.7
Micro-nutrient	0.0	0.0	0.0	0.0
Interculture	21.2	27.3	29.4	0.0
Weeding	47.7	58.0	73.7	74.9
Plant protection	0.0	93.1	0.0	7.8
Irrigation	8.6	35.5	64.2	0.0
Watching	1.1	0.0	0.0	0.0
Harvesting	60.8	110.8	71.8	50.2
Threshing	41.6	0.0	77.2	30.5
Marketing	7.7	11.5	25.8	5.4
Total Variable Cost (TVC)	371.6	686.0	577.0	578.2
Fixed cost/ha	129.5	149.4	193.7	131.6
Total Cost (TC)	501.1	835.4	770.7	709.8
Grain yield (kg ha^{-1})	1680	1588	5780	889.2
Price (USD/ton)	236.3	727.2	236.3	563.6
By-product (kg ha^{-1})	2470	0.0	4190	240.0
Price (USD/ton)	24.5	0.0	28.1	7.3
Gross returns/ha	457.5	1154.8	1483.6	502.9
Net returns over TC	-43.6	319.4	712.9	-206.9
Net returns over VC	85.9	468.8	906.6	-75.3
BCR	0.91	1.38	1.92	0.71

USD 319.4 per hectare. Hence, it yielded a benefit/cost ratio of 1.38. Maize turned out to be the most profitable crop, with a benefit/cost ratio of 1.92. The best lands were allocated to it (the fixed cost was highest at USD 193.7, whose biggest component is the rental value of land). It gave very high yield of 5780 kg per hectare, due to which the gross returns were the highest. Soybean, which was also allocated to poor soils (fixed costs were only USD 131.6 per hectare) did not yield well despite high cost of inputs used. It failed to recover even the variable costs and yielded a low benefit/cost ratio of 0.71.

The comparative economics of pearl millet vis-a-vis its competing crops in WMH are summarized in Table A5. Just as in the case of MTW, the benefit/cost ratio of pearl millet was 0.92. The fixed cost figures indicate that similar quality lands were allocated to pearl millet and cotton, while maize and soybean received good quality lands. The poorest lands were allocated to groundnut. Among the five crops grown in rainy season in WMH, cotton yielded the highest benefit/cost ratio of 1.46, followed by groundnut with 1.34. Soybean and cotton gave similar benefit/cost ratios. Maize yields were about 150% higher than those from pearl millet due to which it emerged as the most profitable crop. Perhaps, it is also receiving

Table A5. Costs and returns of rainy season crops in WMH region.

Activity (USD per ha)	Pearl millet 135 plots	Cotton 31 plots	Maize 44 plots	Soybean 10 plots	Groundnut 9 plots
Land preparation	51.7	53.7	54.3	52.8	50.8
Seed bed preparation	1.1	18.2	19.1	4.5	12.7
Compost/Animal penning	23.7	25.5	47.0	35.6	20.7
Planting	32.7	31.7	37.6	36.5	37.7
Seed cost	15.9	65.3	58.7	83.8	170.3
Seed treatment	0.0	0.0	0.4	0.2	0.0
Fertilizer cost	42.9	80.56	84.7	68.4	35.9
Micro-nutrient	0.1	4.4	6.8	0.0	1.7
Interculture	7.7	22.6	14.6	0.0	0.0
Weeding	41.3	51.6	64.4	51.1	58.6
Plant protection	0.0	49.4	0.76	10.8	0.0
Irrigation	9.1	14.5	39.8	4.0	12.0
Watching	1.1	0.0	0.0	0.0	0.0
Harvesting	50.7	83.1	57.7	48.3	49.0
Threshing	43.2	0.0	80.6	43.0	41.5
Marketing	7.9	10.8	20.6	7.3	5.9
Total Variable Cost (TVC)	329.1	511.4	587.1	446.3	496.8
Fixed cost/ha	185.6	184.6	233.3	243.0	160.2
Total Cost (TC)	514.7	696.0	820.4	689.3	657.0
Grain yield (kg ha^{-1})	1813	1215	4577	1563	1235
Price (USD/ton)	236.3	672.7	236.3	509	691
By-product (kg ha^{-1})	2470	0.0	4190	740	990
Price (USD/ton)	19.0	0.0	27.0	26.7	27.2
Gross returns/ha	475.3	817.3	1194.7	815.3	880.3
Net returns over TC	-39.4	121.4	374.3	126.0	223.3
Net returns over VC	146.2	306.0	607.6	369.0	383.5
BCR	0.92	1.17	1.46	1.18	1.34

protected irrigation in several cases. Other crops are receiving attractive prices which rendered them more profitable than pearl millet. Pearl millet could recover all variable costs and also a good part of the fixed costs, despite 2012-13 being a sub-normal year in terms of rainfall.

The pooled data for Maharashtra were analyzed to assess the comparative economics of rainy season crops in 2012-13, and are presented in Table A6. Pearl millet, which yielded similar benefit/cost ratios in both the regions, had the same ratio of 0.92. Soybean, which returned losses in MTW and profits in WMH could just break even (1.03). Cotton gave a decent benefit/cost ratio of 1.27, but maize was the most profitable crop during the rainy season of 2012-13, with the benefit/cost ratio of 1.54. The fixed cost figures suggest that pearl millet and cotton were grown on poor quality land, while maize and soybean were allocated better quality land. Maize was profitable due to the higher yields it could give, while cotton and soybean received attractive prices due to which the returns could cover all the costs of cultivation and provide handsome profits as well.

Table A6. Costs and returns of rainy season crops in Maharashtra state.

Activity (USD per ha)	Pearl millet 179 plots	Cotton 65 plots	Maize 54 plots	Soybean 15 plots
Land preparation	52.7	56.8	54.2	54.9
Seed bed preparation	1.3	22.4	18.7	10.5
Compost/animal penning	23.6	37.9	38.3	72.2
Planting	32.4	31.9	35.2	35.7
Seed cost	15.8	69.3	60.2	81.1
Seed treatment	0.0	0.0	0.4	0.1
Fertilizer cost	45.9	95.6	82.6	69.9
Micro-nutrient	0.1	2.1	5.5	0.0
Interculture	11.0	25.0	17.4	0.0
Weeding	42.9	55.0	66.1	59.0
Plant protection	0.0	72.3	0.6	9.8
Irrigation	8.9	25.5	44.3	2.6
Watching	1.1	0.0	0.0	0.0
Harvesting	53.3	97.6	60.3	48.9
Threshing	42.8	0.0	79.9	38.9
Marketing	7.9	11.1	21.5	6.6
Total Variable Cost (TVC)	339.7	602.5	585.2	490.2
Fixed cost/ha	171.8	166.2	225.9	205.9
Total Cost (TC)	511.5	768.7	811.1	696.1
Grain yield (kg ha^{-1})	1781	1410	4799	1338
Price (USD/ton)	236.3	690.9	236.3	527.2
By-product (kg ha^{-1})	2470	0.0	4200	490
Price (USD/ton)	20.3	0.0	27.0	20.1
Gross returns/ha	471.0	974.2	1247.4	715.2
Net returns over TC	-40.5	205.5	436.3	19.1
Net returns over VC	131.3	371.7	662.2	225.0
BCR	0.92	1.27	1.54	1.03

The economics of postrainy season crops during 2012-13 in MTW region are presented in Table A7. The rental values of land suggest that sorghum is getting poor quality of land, while wheat is getting better quality land with some irrigation facility and onion is getting the best quality land and irrigation support. All the crops in postrainy season were profitable during 2012-13. Sorghum gave a benefit/cost ratio of 1.25 on the strength of higher grain and fodder prices. Wheat gave a higher benefit cost of 1.56 because of high yield, while onion yielded a phenomenal benefit/cost ratio of 2.69 on the strength of both high yield as well as attractive price.

Table A7. Costs and returns of postrainy season crops in MTW region.

Activity (USD per ha)	Sorghum 7 plots	Wheat 8 plots	Onion 5 plots
Land preparation	56.1	55.0	42.2
Seed bed preparation	0.0	13.3	26.0
Compost/animal penning	25.6	0.0	0.0
Planting	0.0	25.7	100.4
Seed cost	6.0	39.0	176.4
Seed treatment	0.0	0.0	0.0
Fertilizer cost	44.5	52.4	197.3
Micro-nutrient	0.0	0.0	3.5
Interculture	9.6	0.0	0.0
Weeding	27.8	52.1	122.7
Plant protection	0.0	4.1	59.6
Irrigation	29.6	84.9	175.4
Watching	0.0	0.0	0.0
Harvesting	51.7	49.2	205.1
Threshing	32.4	26.2	0.0
Marketing	1.4	15.1	231.3
Total Variable Cost (TVC)	284.7	417.0	1339.9
Fixed cost/ha	128.8	197.0	252.0
Total Cost (TC)	413.5	614.0	1591.9
Grain yield (kg ha^{-1})	1447	3297	26182
Price (USD/ton)	290.9	290.9	163.6
By-product (kg ha^{-1})	2220	0.0	0.0
Price (USD/ton)	43.4	0.0	0.0
Gross returns/ha	517.3	959.1	4283.4
Net returns over TC	103.8	345.1	2691.5
Net returns over VC	232.6	542.1	2943.5
BCR	1.25	1.56	2.69

The comparative economics of postrainy season crops during 2012-13 in WMH are presented in Table A8. In this region, sorghum could recover only the variable costs and about 50% of the fixed costs. The benefit/cost ratio was only 0.80 from the sorghum crop. Wheat and chickpea gave normal profits, with benefit/cost ratios of 1.31 and 1.43, respectively. Onion crop gave extraordinary profits due to high yields and prices, with a phenomenal benefit/cost ratio of 4.61. The fixed cost figures indicate that sorghum received poor quality lands, while the other crops were allocated better quality land along with irrigation facilities.

Table A8. Costs and returns of postrainy season crops in WMH region.

Activity (USD per ha)	Sorghum 38 plots	Onion 29 plots	Chickpea 9 plots	Wheat 22 plots
Land preparation	45.3	46.5	50.5	48.0
Seed bed preparation	1.3	30.9	0.0	9.2
Compost/animal penning	7.9	101.7	41.4	27.4
Planting	30.9	58.5	0.0	29.5
Seed cost	8.0	208.1	86.8	37.6
Seed treatment	0.2	0.0	0.0	0.7
Fertilizer cost	38.9	139.9	39.1	82.1
Micro-nutrient	0.0	6.3	0.0	0.4
Interculture	5.1	2.7	3.2	0.0
Weeding	34.7	82.4	39.3	52.2
Plant protection	1.3	61.3	8.9	2.2
Irrigation	9.7	103.6	15.9	74.3
Watching	0.3	0.0	0.0	0.0
Harvesting	43.9	128.5	47.8	55.7
Threshing	19.7	0.0	34.1	46.5
Marketing	2.7	147.8	5.9	14.4
Total Variable Cost (TVC)	249.9	1118.2	372.9	480.2
Fixed cost/ha	135.4	318.0	245.0	214.9
Total Cost (TC)	385.3	1436.2	617.9	695.1
Grain yield (kg ha^{-1})	753.3	24305	1391	2947
Price (USD/ton)	272.7	272.7	636.3	309.0
By-product (kg ha^{-1})	2220	0.0	0.0	0.0
Price (USD/ton)	45.6	0.0	0.0	0.0
Gross returns/ha	306.7	6628.0	885.1	910.6
Net returns over TC	-78.6	5191.8	267.2	215.5
Net returns over VC	56.8	5509.8	512.2	430.4
BCR	0.80	4.61	1.43	1.31

Data pooled over the two regions were analyzed and the economics of the postrainy season crops for 2012-13 seasons in Maharashtra are summarized in Table A9. Due to of the large weight the WMH region has in the Maharashtra sample, the pooled results very much resemble those in Western Maharashtra. The benefit/cost ratio was only 0.84 for sorghum, as the gross returns fell short of total costs by USD 63.90. Chickpea and wheat crops gave reasonable profits, while onion gave very high benefit/cost ratio of 4.29 due to very high prices received for the product.

Table A9. Costs and returns of postrainy season crops in Maharashtra state.

Activity (USD per ha)	Sorghum 58 plots	Onion 34 plots	Chickpea 14 plots	Wheat 30 plots
Land preparation	49.6	45.9	47.6	49.9
Seed bed preparation	0.8	30.2	5.11	10.2
Compost/animal penning	7.2	86.7	0.0	20.1
Planting	31.3	64.6	36.3	28.5
Seed cost	7.8	203.5	82.5	37.9
Seed treatment	0.1	0.0	0.0	0.5
Fertilizer cost	42.3	148.3	39.9	74.1
Micro-nutrient	0.0	5.9	0.0	0.3
Interculture	7.9	2.2	2.0	0.0
Weeding	36.8	88.3	43.6	52.2
Plant protection	0.8	61.1	7.4	2.7
Irrigation	12.6	114.2	10.2	77.1
Watching	1.2	0.0	0.0	0.0
Harvesting	49.4	139.8	48.7	54.0
Threshing	22.9	0.0	30.7	41.1
Marketing	3.9	160.1	4.8	14.6
Total Variable Cost (TVC)	274.6	1150.8	358.8	463.2
Fixed cost/ha	133.3	308.3	196.2	210.1
Total Cost (TC)	407.9	1459.1	555.0	673.3
Grain yield (kg ha^{-1})	904.0	24581	1158	3040
Price (USD/ton)	272.2	254.5	636.3	309.0
By-product (kg ha^{-1})	2220	0.0	0.0	0.0
Price (USD/ton)	44.1	0.0	0.0	0.0
Gross returns/ha	344.0	6255.9	736.8	939.4
Net returns over TC	-63.9	4796.8	181.8	266.1
Net returns over VC	69.4	5105.1	378.0	476.2
BCR	0.84	4.29	1.33	1.40

ICRISAT INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS

CGIAR ICRISAT is a member of the CGIAR System Organization

We **believe** all **people** have a **right** to **nutritious food** and a **better livelihood.**

ICRISAT works in agricultural research for development across the drylands of Africa and Asia, making farming profitable for smallholder farmers while reducing malnutrition and environmental degradation.

We work across the entire value chain from developing new varieties to agri-business and linking farmers to markets.

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245-2016

ISBN 978-92-9066-581-6