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Prospects for *kharif* (Rainy Season) and Summer Pearl Millet in Western India

A Amarender Reddy, P Parthasarathy Rao, OP Yadav, IP Singh, NJ Ardeshna, KK Kundu, SK Gupta, Rajan Sharma, Sawargaonkar G, Dharm Pal Malik, D Moses Shyam and K Sammi Reddy

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Abstract

Pearl millet is a major cereal crop in northwestern India. The crop is grown in very harsh, arid, dry climatic areas having high temperature and low and erratic rainfall. It's use as food is declining but its use as cattle feed, poultry feed and source of starch in the alcohol industry is increasing. Its fodder is an important source of animal feed particularly in dry months when alternative sources of feed are not available. In the last decade, pearl millet was also grown under irrigation in the summer months. Gujarat state has the highest area under summer pearl millet not only among the northwestern states but also at the all-India level. In this paper, we have analyzed the productive potential of both kharif (rainy season) and summer pearl millet particularly in Gujarat state. Kharif pearl millet still contributes to the bulk of the pearl millet production in western India although its yields are relatively low. To compete with crops like guar, green gram, cotton, etc, both grain and fodder yields of the kharif crop need to be increased. With the adoption of improved cultivars and low-cost improved technology, yields can be increased by 20-30% from the existing levels. Yields of summer pearl millet are much higher since it is grown under irrigation and its grain quality is also superior. It is grown as a commercial crop with the bulk of the crop sold domestically, and also exported to neighboring countries. There is a need to explore opportunities to expand the area under summer pearl millet particularly in areas where irrigation is available and the fields are vacant during the summer season.

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Contents

Acronyms

ACGR	Annual Compound Growth Rate
AICPMIP	All India Coordinated Pearl Millet Improvement Project
APMCS	Agricultural Produce Marketing Committees
CACP	Commission for Agricultural Costs and Prices
CPI	Consumer Price Index
CRIDA	Central Research Institute for Dry land Agriculture
DES	Directorate of Economics and Statistics (DES)
GSCMF	Gujarat State Cooperative Marketing Federation
Ha	Hectare
HOPE	Harnessing Opportunities for Productivity Enhancement of Sorghum and Millets in Sub-Saharan Africa and South Asia
HYVs	High Yielding Varieties
II	Instability Index
IMOD	Inclusive Market Oriented Development
Kg	Kilograms
MSP	Minimum Support Price
Mt	Million tons
NSKE	Neem Seed Kernel Extract

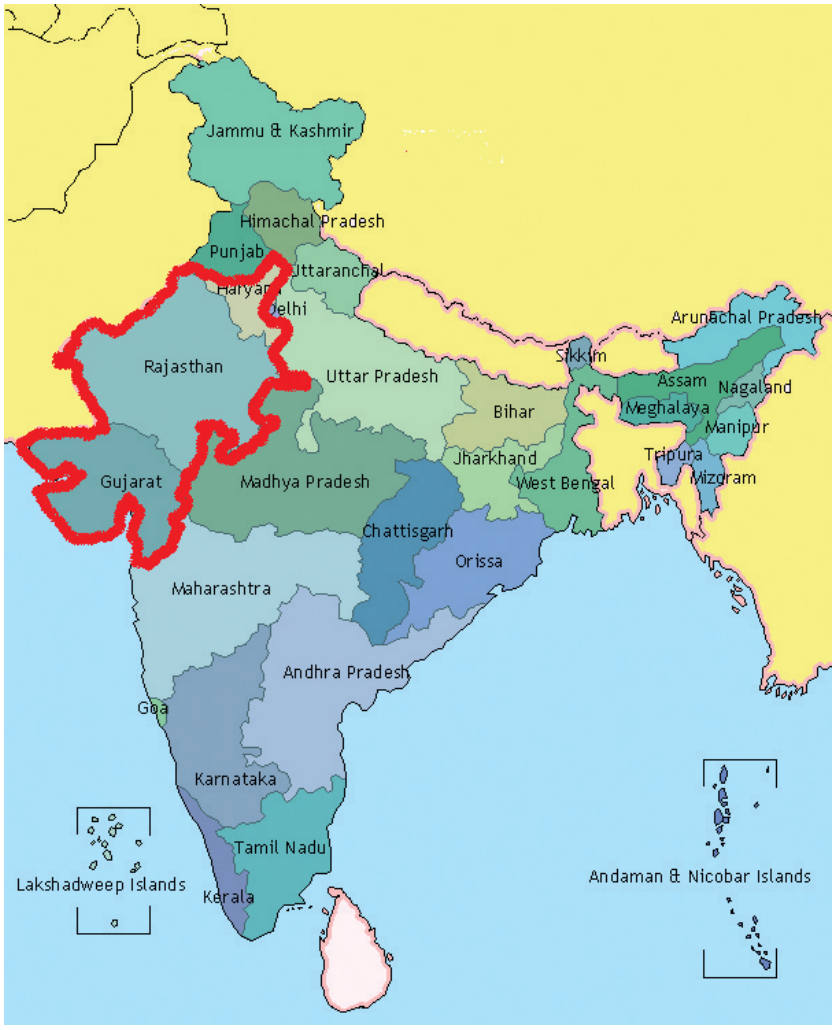
Introduction

Pearl millet is the most drought tolerant warm season cereal grown on 27 million ha in some of the harsh, arid and dry-semi-arid tropical environments of South Asia and sub-Saharan Africa. It is more tolerant to high temperatures than any other cereal. The best temperature for the germination of pearl millet seed is from 23 to 32°C. The optimum rainfall requirement of pearl millet ranges between 500-800 mm and it can also be successfully grown in areas that receive less than 500 mm of annual rainfall. However, prolonged intra-seasonal spells of warm, rain-free weather may be detrimental to its growth and may lead to reduced crop yields. Although pearl millet can respond to good moisture availability during its growth, it is nevertheless one of the toughest, drought tolerant crops available and has a distinct advantage over competing crops in the regions where there is scanty and erratic rainfall and high temperatures. The ability of the crop to grow in dry environments is due to a number of physiological and morphological characteristics, (i) rapid and deep root penetration (root depths of 3.6 m have been recorded); (ii) fast growth and development; and (iii) high tillering capacity.

India has the largest area (about 8.5 million ha) under pearl millet, which ranks third in area after rice and wheat among cereals. Although the crop is grown in several states of the country, it is a major crop in the dry areas of northwestern India, which comprises parts of Gujarat, Rajasthan and Haryana (Map 1). It is valued for both its grain and stover. Its grains have high protein content, balanced amino acid profile, and high levels of iron, zinc and insoluble dietary fibre and are the major source of dietary carbohydrates in the human diet. Its stover is an important component of livestock ration during the dry period of the year.

Pearl millet is cultivated in both *kharif* and summer seasons in northwestern India. The recent spurt in prices of food grains especially of coarse cereals indicates supply-side constraints to meet their growing demand for non-food uses mainly for poultry; cattle feed, alcohol and starch industry. Further, with the higher prices of wheat, rice and maize in recent years, cattle and poultry feed and alcohol industries are looking for cheaper alternative sources like pearl millet. It is also noted that demand for pearl millet from the health-conscious food products industry is increasing as it contains more fibre and is good for diabetic and heart patients. However, due to the high instability in grain yields and decline in prices of pearl millet, farmers might shift to other competing crops. The cultivation of pearl millet during the summer might reduce the instability as the crop is grown under irrigated conditions, which gives higher yields and returns. The area under summer pearl millet is still low when compared to *kharif* pearl millet but it is expanding in Gujarat state. Pearl millet is also an important fodder crop in the summer season, as most of the other crops cannot withstand hot temperatures. However, there are some abiotic and biotic constraints in cultivation of pearl millet, such as downy mildew, stem borer, shoot fly, drought, extreme heat and moisture stress.

In view of pearl millet's importance in the *kharif* season in terms of area and production, and the scope for expanding its area in summer due to significant higher yields, this paper looks at area and production trends of pearl millet in India and northwestern India (particularly Gujarat). The paper also attempts to examine the comparative economics of pearl millet in both *kharif* and summer seasons in order to (i) assess competitiveness of *kharif* and summer pearl millet in western India (ii) examine the possibility of enhancing overall yield by expanding the area under summer season, and (iii) explore scope for increasing yield further, reducing instability and increasing competitiveness of *kharif* pearl millet.



Map 1. Map of India showing study area.

Data and methodology

The secondary data at district/state level on area, production and yield is taken from the Directorate of Economics and Statistics (DES), Ministry of Agriculture, Government of India. Data on annual prices of major crops in India is drawn from FAOSTAT price archives from 1961 to 2010 to measure trends in real prices. Prices were deflated by consumer price index (CPI) for agricultural laborers with 1986/87 base year to get real prices. Cost of cultivation data for pearl millet is compiled from DES, Government of India. Since the DES does not provide separate data for *kharif* and summer pearl millet, the secondary data collected is supplemented by primary data collected in the year 2009/10 and 2010/11 under the project titled 'Harnessing Opportunities for Productivity Enhancement of Sorghum and Millets in Sub-Saharan Africa and South Asia (HOPE)' of ICRISAT. Seasonal trends in market arrivals and price trends of pearl millet are collected from Agricultural Marketing Produce Committees (APMCs) in Radhanpur, Tharad, Palanpur, Deesa, Patan and Ahmedabad under the HOPE project in western India. The simple averages, triennium ending averages, trends, instability index, and cost benefit ratios are used for analysis of the data.

Results

Trends in area, production and productivity

All-India

At the all-India level between 1961 and 2009, despite a decline in area under pearl millet, the faster increase in yield from about 400 kg/ha to more than 1000 kg/ha helped to increase production from 3.28 million tons (mt) in 1961 to 8.89 mt in 2009 (Figure 1). The significant yield increase was achieved despite the fact that the bulk of the crop is grown under rainfed conditions. The irrigated area under the crop increased slowly from around 3% in the sixties to around 10% in 2009. Much of the yield increase can be attributed to improved cultivars (varieties and hybrids) with higher yields compared to traditional landraces. In northwestern India, except in western Rajasthan, the majority of the area is under improved cultivars.

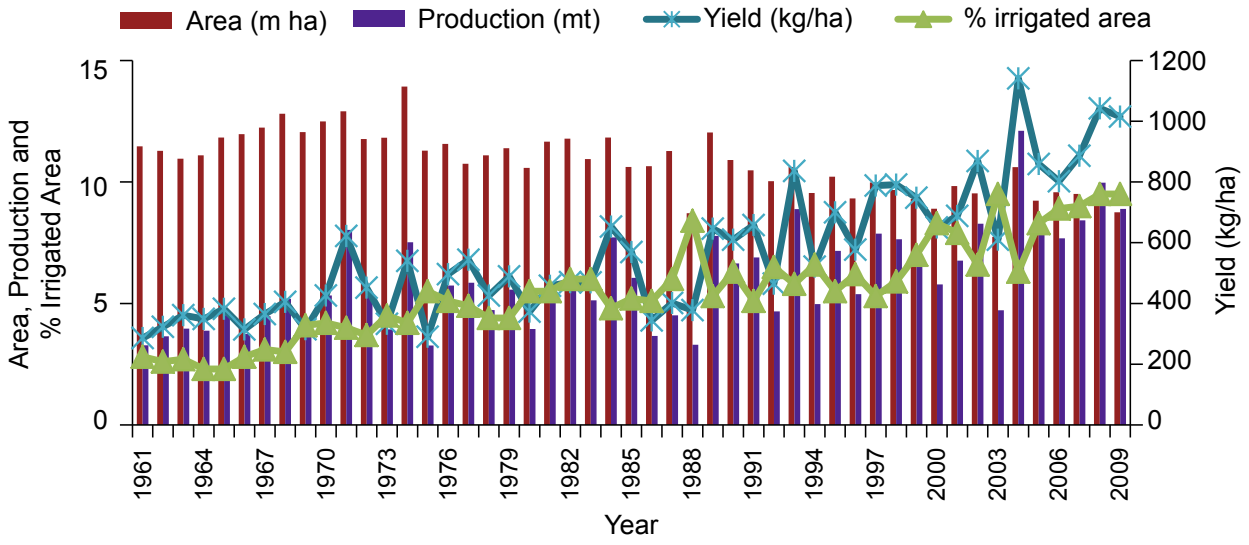


Figure 1. Pearl millet area, production, % irrigated area and yield in India.
Source: Directorate of Economics and Statistics (2011).

Among the coarse cereals, growth in area under sorghum and pearl millet has decreased, while area under maize has increased between 1985 and 2009 (Figure 2). However, the decline in pearl millet area is slower than for sorghum. The growth of pearl millet yield is higher than for both sorghum and maize during 1995-2009. Thus, the average yield of pearl millet in early 1960s was less than sorghum, but by 2009 it was slightly higher (981 kg/ha for pearl millet compared to 943 kg/ha for sorghum) (Table 1). Pearl millet yields were, however, still about half of that of maize yield (2251 kg/ha) and 1/3rd of that of wheat (2806 kg/ha) due to their higher initial yield levels.

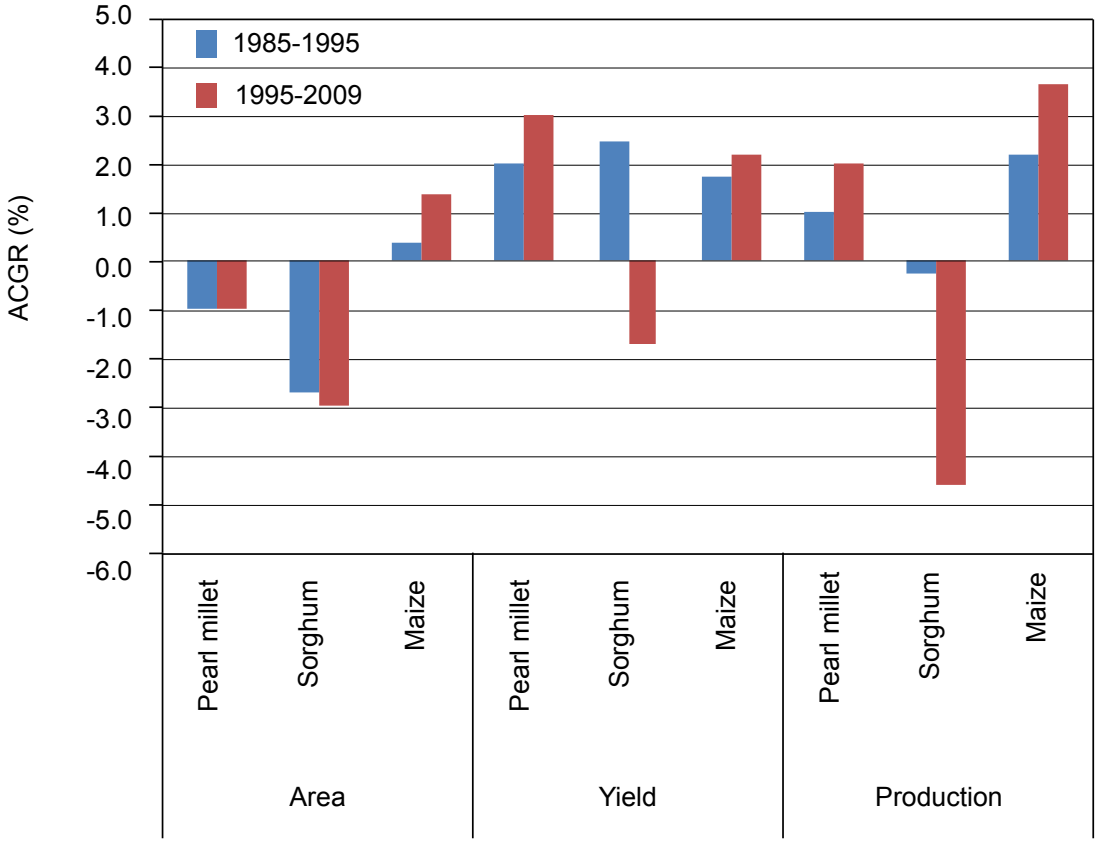


Figure 2. ACGR (%) of coarse cereals in India.
Source: Directorate of Economics and Statistics (2011).

Besides yields, prices also determine the competitiveness of crops. The real prices of pearl millet decreased by 17.4% from 1969 to 2009 while the decrease is less for wheat and sorghum. For some competing crops like pulses, real prices actually increased during the same period (Table 1).This reduced the competitive position of pearl millet in the cropping systems.

Table 1.Trends in real prices (Rs/quintal) of food grains in India.

Crop	% change in real prices between 1969 and 2009	% change in production between 1969 and 2009	Yield TE 2009 (kg/ha)
Pearl millet	-17.4	91	981
Sorghum	-6.3	-24.5	943
Maize	-18.9	214	2251
Wheat	-10.2	405	2806
Chickpea	42.0	37.6	834
Pigeonpea	32.9	63.4	715

Source: FAOSTAT (2011); prices were deflated by CPI for agricultural labor with 1986/87 base year.

Table 2 presents the mean and instability index (II) for area, yield, production and % area under irrigation with respect to pearl millet and a few other selected crops from 1961-70 and 2000–2009. The area under both sorghum and pearl millet has declined, while maize and wheat has increased (Pray and Nagarajan 2009). However, it is to be noted that the instability of area, yield and production of pearl millet has increased significantly, whereas for other crops like maize, sorghum and wheat it has decreased. The instability is higher in pearl millet mainly because it is grown under rainfed conditions in harsh environments. The instability is higher than that of sorghum since sorghum is grown under better rainfall regimes. For crops like maize and wheat, as their area under irrigation has increased, instability in production has declined. Hence, there is a need for the development of biotic and abiotic stress tolerant varieties and expansion of area under summer season.

Table 2. Changes in mean and Instability Index (II) of major cereals in India.

		Area (mha)		Yield (kg/ha)		Production (mt)		% irrigated area	
Crop	Year	Mean	II	Mean	II	Mean	II	Mean	II
Pearl millet	1961-70	12.5	0.04	426	0.18	5.3	0.20	4.2	0.14
	2000-09	9.3	0.15	981	0.29	9.1	0.43	9.3	0.23
Sorghum	1961-70	18.6	0.02	522	0.14	9.7	0.15	4.1	0.07
	2000-09	7.9	0.03	942	0.10	7.4	0.08	8.5	0.09
Maize	1961-70	5.9	0.03	968	0.07	5.7	0.09	18.2	0.25
	2000-09	8.1	0.03	2220	0.12	17.9	0.14	22.8	0.06
Wheat	1961-70	16.6	0.06	1208	0.13	20.1	0.17	51.1	0.08
	2000-09	27.9	0.04	2806	0.04	78.4	0.07	90.7	0.01

Note: Instability index(II) = Standard deviation of natural logarithm (Yt+1/Yt) where, Yt is the area / production / yield in the current year and Yt+1 is for the next year (Chand and Raju 2009). This index is unit free and very robust, and it measures deviations from the underlying trend (log linear in this case). When there are no deviations from trend, the ratio of Yt+1/ Yt is constant and thus standard deviation is zero. As the series fluctuates more, the ratio of Yt+1 and Yt also fluctuates more, and standard deviation increases.

Source: Directorate of Economics and Statistics (2011).

Northwestern India

Northwestern India accounts for 72% of all-India area under pearl millet and 66% of its production (Table 3). The yield levels are modest at 860 kg/ha,which is slightly lower than the all-India average yield levels. Within northwestern India, Rajasthan accounts for highest area and production followed by Gujarat and Haryana. Yield levels are the lowest in Rajasthan (650 kg/ha) while it is 1300 and 1700 in Gujarat and Haryana, respectively. Haryana has high yield rates because more than 40% of the area under pearl millet is irrigated (partially with supplemental irrigation). In Gujarat, most of the summer pearl millet area is irrigated, which contributes to high overall yields. Also, in both the states, improved cultivars have replaced local landraces. In Rajasthan, in contrast, the bulk of pearl millet is grown in rainfed conditions and landraces still account for close to 50% of the total area in western districts. Between 1990 and 2009, the area under pearl millet has been declining in Gujarat and stagnant in Haryana and Rajasthan. In contrast, production is increasing in both Haryana and Rajasthan by more than 4% per annum. The major driver of production growth is yield increase in both the states. Also, in Gujarat, despite the declining area,

Table 3. Pearl millet area, production and yield, 2007-09 and their compound annual growth rates, 1990-2009.

	Area		Production		Yield	
Region/State	(000 ha)	Growth rate (%)	(000 tons)	Growth rate (%)	(kg/ha)	Growth rate (%)
Western India	6,513 (72)	0.003	5,600 (66)	3.12	860	3.1
Gujarat	764 (8)	-2.4	1,032 (12)	-0.3	1352	2.15
Haryana	610 (7)	0.25	1,057 (13)	4.49	1733	4.24
Rajasthan	5,139 (57)	0.45	3,511 (42)	4.17	683	3.7
All India	9,080	-0.62	8,455	1.82	931	2.46

Note: Figures in parenthesis indicate share to all-India

production is holding on due to yield growth. There is considerable fluctuation in pearl millet yields in western India and there is also a high correspondence between year to year fluctuations in yield and production levels (Figures 3, 4, 5).

Summer pearl millet is an emerging niche area for pearl millet production in northwestern India, grown under irrigated conditions during April–June when other crops are not commonly grown. Within the northwestern states of India, the area under summer pearl millet has expanded rapidly in Gujarat and now accounts for the highest area and production in the region. In Gujarat, between 2004-05 and 2008-09 the share of summer pearl millet area in total pearl millet area increased from 16% to 25% while share of kharif pearl millet declined (Table 4). However, the production share of summer pearl millet is 44% in total pearl millet production since its yields are more than twice of kharif pearl millet (Table 5).

Within Gujarat, 8 districts account for more than 75% of the area and production of pearl millet with highest area and production in Banaskanta district. These districts account for almost 90% of the area and production under summer pearl millet. For summer pearl millet also, Banaskanta is the leading district with more than 40% of the area and production followed by Anand and Kheda (Table 6). The yield of summer pearl millet is two times higher than that of the *kharif* pearl millet. As summer pearl millet is cultivated as an irrigated crop, yield fluctuations are less. The district level data indicates that there is a negative relationship between percent area under pearl millet cultivation and the rainfall of the district. However, there is a positive relation between percent area under summer pearl millet and percent area under irrigation. Considering farmers' willingness to invest more money for cultivation of summer pearl millet because of higher profits, the private sector is active in marketing hybrid seeds for summer cultivation and hence, improved varieties/ hybrids are popular in summer. A few fodder varieties have also been developed to meet the growing demand for fodder. The forage types are much taller (7-8 feet), having good succulency and fodder value and mostly grown in peri-urban areas.

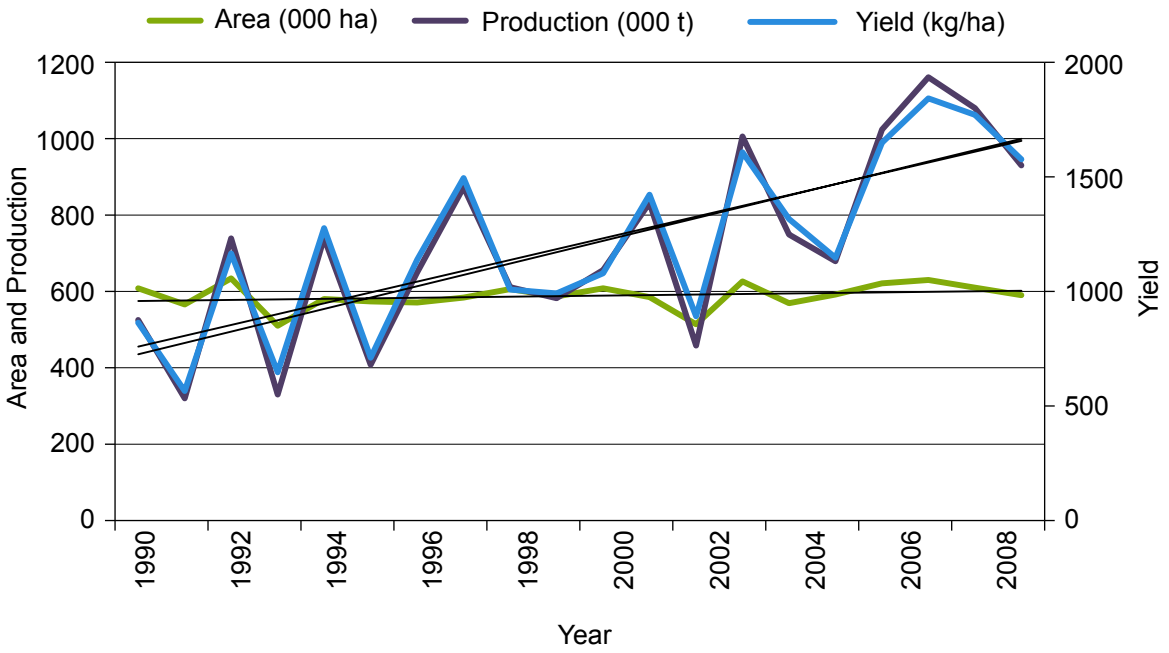


Figure 3. Area, Production and Yield - Pearl Millet, Haryana.

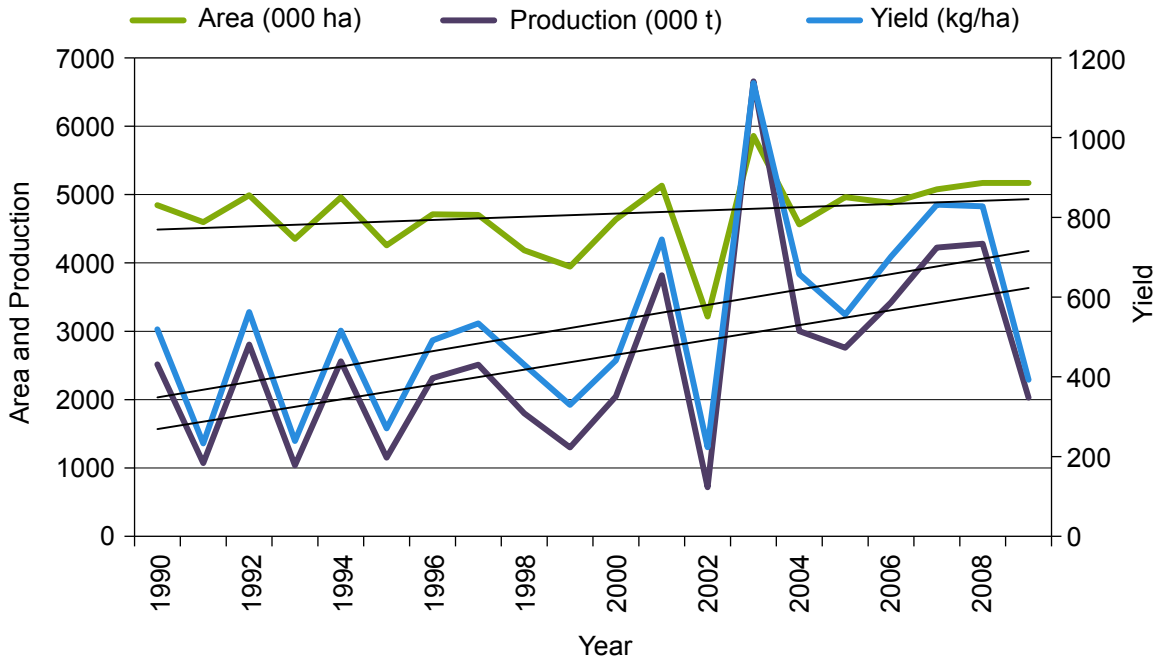


Figure 4. Area, Production and Yield - Pearl Millet, Rajasthan.

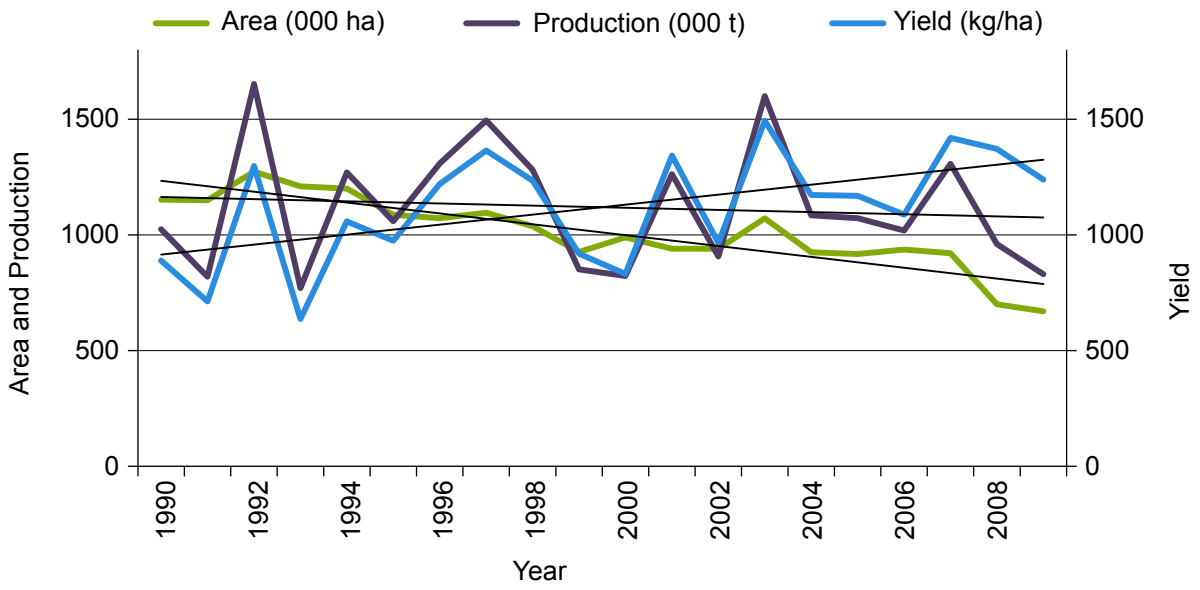


Figure 5. Area, Production and Yield - Pearl Millet, Gujarat.

Table 4. Pearl millet area and production in Gujarat during summer and *kharif* seasons.

Year	Summer	Share (%)	Kharif	Share (%)
		Area ('000 ha)		
2004-05	145.0	16	770.1	84
2005-06	164.4	17	781.6	83
2006-07	183.4	20	742.3	80
2007-08	193.4	21	728.2	79
2008-09	174.6	25	528.7	75
		Production ('000 t)		
2004-05	303.1	28	785.9	72
2005-06	374.5	31	831.3	69
2006-07	428.5	45	528.4	55
2007-08	454.9	35	851.7	65
2008-09	426.1	44	535.2	56

Table 5. Pearl millet yield (kg/ha) in Gujarat during summer and *kharif* seasons.

	Summer	Kharif	Total
2004-05	2,090	1,021	1,190
2005-06	2,278	1,064	1,275
2006-07	2,337	712	1,034
2007-08	2,352	1,170	1,418
2008-09	2,440	1,012	1,367

Table 6. Shares of pearl millet area and production in districts in Gujarat (%).

District	Share in total pearl millet area	Share in total pearl millet production	Share in summer pearl millet area	Share in summer pearl millet production
Banaskantha	29.1	21.4	42.8	40.9
Patan	8.97	5.79	2.69	3.0
Bhavnagar	6.8	11.3	2.0	2.01
Mehsana	8.4	9.9	8.13	8.72
Kheda	9.1	9.8	11.16	11.31
Anand	6.9	9.7	11.26	12.03
Gandhi Nagar	3.46	4.87	5.32	5.86
Sabarkantha	1.92	2.66	4.92	5.04
Total	74.6	75.4	88.2	88.8

Relative profitability of *kharif* and summer pearl millet compared to competing crops

As discussed, the area under pearl millet is marginally declining or stagnant and there is a probability of further decline in area under *kharif* pearl millet due to expansion of area under more remunerative and high value crops such as pulses and oilseeds (green gram, black gram, sesamum, guar, etc), which fetch higher profit as the prices and demand of these crops increased more relative to that of pearl millet in the last decade. Further expansion of irrigated area also leads to replacement of pearl millet with other crops like cotton, which is highly remunerative under irrigated conditions. Hence, the scope of expanding the area under *kharif* pearl millet exists only in low rainfall districts with little scope for expanding irrigation facilities. However, there is still a large pearl millet area under *kharif* season in western India, hence, it is important to increase pearl millet production through all the best possible interventions in this season. For example, the existing low yields can be tackled by adoption of improved cultivars and improved package of practices that will enhance yield even in marginal environments and under aberrant weather conditions.

Expanding pearl millet area during the summer season under irrigated conditions is another option. Presently, the bulk of the summer pearl millet area is in Gujarat and efforts should be made to increase the per unit productivity of summer pearl millet besides looking for further area expansion. The market survey in Agricultural Marketing Produce Committees (APMCs) in Radhanpur, Tharad, Palanpur, Deesa, Patan and Ahmedabad shows that the summer pearl millet is cultivated mostly as a commercial crop in Gujarat with almost 100% of production marketed just after harvest with peak market arrivals in the month of June (Figure 6). However, the major problem in expanding the summer pearl millet area and production is finding niches with irrigation facilities, and low storability of summer harvest due to onset of monsoon in the months of July-August. Since the monsoon begins just after harvest, this may spoil the grain quality under ordinary storage conditions. The bulk of the summer pearl millet is shipped outside the growing area to neighboring districts/ states for food use. Second quality grain goes for cattle feed. Grayish-white grain with elongated shape has a good export market (mainly Gulf countries) for use in poultry feed and other such uses. The stalk of summer pearl millet is also valued for its thin stem.

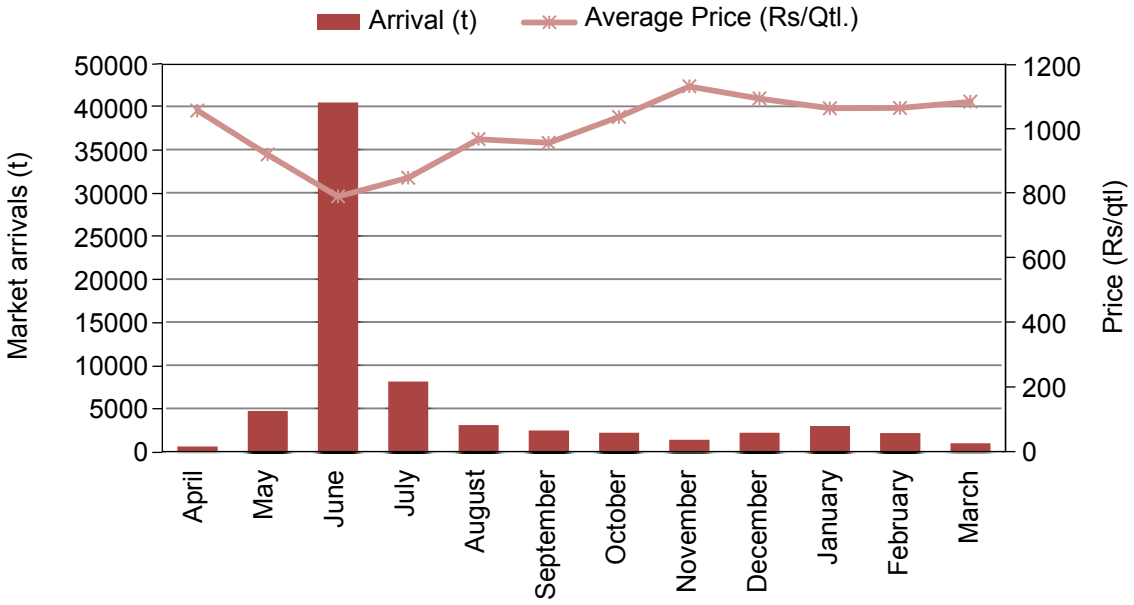


Figure 6. Market Arrivals and Prices in selected Gujarat markets.

Output and Input Markets

In western India, input and output markets are reasonably developed. All states have regulated markets for grain while only some states have regulated markets for fodder. However, the fodder trade is mostly done in informal markets with a few commission agents facilitating the trade between sellers and buyers. Input (seed, fertilizer, pesticides, credit, etc) marketing is done by both private and public agencies. In Gujarat, the *Taluka* (which is an intermediate administrative unit comprising 50 to 60 villages) level cooperative purchase and sale units under the umbrella organization of Gujarat State Cooperative Marketing Federation (GSCMF) sells fertilizer, seed and pesticides, and procures agricultural commodities at minimum support price (MSP). Although a number of seed companies are involved in marketing seed requirements of *kharif* pearl millet, they are more interested in seed marketing of commercial crops like cotton and high-volume business crops. The private seed companies are more actively involved in meeting hybrid-seed requirements of summer pearl millet as farmers are willing to invest more to purchase the high-cost seed and other inputs (including irrigation) due to assured higher yields. However, some farmers complain about the poor quality of the seed and authenticity of the numerous small seed companies, even though they are satisfied with seed supplied from large private companies. It is interesting to note that in Gujarat in 2010, about 96% of pearl millet area was mainly under High Yielding Varieties (HYVs), the expansion occurring in the last few decades. As a result there is spectacular growth in yield of pearl millet from 817 kg/ha in 1990 to 1215 kg/ha in 2010 (Table 7).These are average yields for both *kharif* and summer pearl millet. At local level, *Taluka* (administrative block comprising a few villages) level cooperatives distribute the seed procured from public/private agencies to farmers with a commission of 5% for public sector seed companies and 10% for the private seed companies. The retail prices of private company hybrid seeds are about 3 times higher (Rs 153/kg) than that of the public sector companies (Rs 53/kg). The low (5-6 kg/ha) seed rate also helped farmers to adopt higher-priced seed, which is affordable even for small farmers given the higher yields.

Table 7. Area under HYVs for different cereals in Gujarat.

Indicator	Year	TE 1990	TE 2010	% change
Area under HYVs (%)	Rice	73	87	14
	Wheat	80	87	8
	Maize	41	62	21
	Pearl millet	73	96	23
Yield (kg/ha)	Rice	1267	1631	29
	Wheat	1971	2379	21
	Maize	1076	1440	34
	Pearl millet	817	1216	49

Source: Directorate of Economics and Statistics (2011).

The GSCMF also undertakes government procurement operations at Minimum Support Price (MSP) on behalf of government agencies for pearl millet. However, during most of the years, farm harvest price is above the MSP, hence there was very little procurement operations in pearl millet grain. During most of the years, even though the recommended MSP by the state government is higher than the cost of production, the Central Government fixed MSP is lower than the cost of production based on Commission for Agricultural Costs and Prices (CACP) recommendation (Table 8).

Table 8. Cost of production and Minimum Support Price of pearl millet.

Year	Cost of Production (Rs/q)	MSP recommended by Haryana government (Rs/q)	MSP recommended by CACP (Rs/q)	MSP fixed by Govt. of India (Rs/q)
TE 1999	455	470	350	353
TE 2005	605	607	502	505
TE 2011	896	1033	853	853
2010-11	938	1050	880	880

Source: Cost of Cultivation Scheme(2011), Haryana Agricultural University.

Cost of production and profitability of pearl millet in Gujarat

Cost of cultivation data was obtained from DES, Government of India but they do not separate the data for *kharif* and summer pearl millet. Hence, the cost of cultivation data reported in Table 9 is the average values for the two seasons. More than 50% of the total cost of production is accounted for by labor, ie, human, bullock and machine labor. This is followed by other costs like interest charges and rental value of own land (24%), fertilizer and manure costs (11%), and irrigation charges (6%). Over the years, fertilizer use per ha has increased significantly while bullock labor has declined giving way to machine labor. Seed rate in pearl millet is about 4-5 kg/ha; because of the lower seed rate, it becomes easy for farmers to purchase high-priced private company seed and thus adoption rates are higher. The profitability of pearl millet has been fluctuating over the years, however, of late (2007-08 and 2008-09), there is a general rise in profitability due to

Table 9. Changes in cost of cultivation of pearl millet in Gujarat.

Items	TE 1995	TE 2001	TE 2004	2007-08	2008-09
Seed (Kg/ha)	5	6	6	6.87	6.74
Fertilizer (Kg/ha)	44	80	70	94.49	104.44
Manure (q/ha)	17	18	29	17.54	23.07
Human labor (Man hrs/ha)	541	606	627	655.10	655.87
Animal labor (Pair hrs/ha)	44	37	37	21.49	11.59
Yield (q/ha)	15	15	16	19.47	25.07
Break-up of Cost of Cultivation (Rs/ha)					
Human labor (Rs/ha)	1813 (31.8)	3602 (35.1)	4162 (36.4)	5224 (33.5)	6252.87 (30.01)
Bullock labor (Rs/ha)	610 (10.7)	591 (35.1)	949 (8.3)	647 (4.1)	537.81 (2.58)
Machine labor (Rs/ha)	-	1157 (11.3)	1482 (13.0)	2432(15.6)	3214.2 (15.43)
Seed (Rs/ha)	142 (2.5)	311 (3.0)	374 (3.3)	715(4.6)	833.25 (4.00)
Fertilizer & manure (Rs/ha)	371 (6.5)	1188 (11.6)	1377(12.0)	1742(11.2)	2000.56 (9.6)
Insecticides (Rs/ha)		0 (0.0)	2 (0.1)	11(0.1)	49.13 (0.24)
Irrigation charges (Rs/ha)		752 (7.3)	575 (5.0)	949(6.1)	1624.3 (7.80)
Interest charges, depreciation rental value of own land (Rs/ha)	2772 (48.6)	2647 (25.8)	2514 (22.0)	3873(24.8)	6233.26 (29.92)
Total cost C2 (Rs/ha)	5708 (100)	10248 (100)	11435 (100)	15593(100)	20836.18 (100)
Value of main production (Rs/ha)	5591 (77.1)	9033 (73.3)	8270 (70.7)	15164(77.4)	21053.47 (74.5)
Value of by-production (Rs/ha)	1661 (22.9)	3287 (26.7)	3429 (29.3)	4418(22.6)	7178.31 (25.5)
Net profit over C2 (Rs/ha)	1544	2072	264	5224	7395
Cost-benefit ratio	1.27	1.20	1.02	1.25	1.35
Cost of production (Rs/q)	380	514	496	611	615

Note : Cost (C2)= all actual expenses in cash & kind incurred in production by farmer, plus interest on value of owned capital assets (excluding land), plus rental value of owned land & rent paid for leased-in-land, plus imputed value of family labor.
Source: Directorate of Economics and Statistics (2011) Cost of cultivation scheme, Government of India.

higher yields and rising prices of grain and fodder. One interesting point of observation is that the share of value of by-product in total value (grain and fodder) ranges between 22.9% and 29.3%, which suggests that the relative price of fodder increased more compared to that of the grain. It also suggests the higher share of research and development efforts that are required towards increasing quality and yield of fodder from pearl millet cultivation.

Cost structure and profitability of *kharif* and summer pearl millet

Since separate data for *kharif* and summer pearl millet are not available from published sources, the cost structure of *kharif* and summer pearl millet was collected under the HOPE project under recommended resource management regime for year 2009/10 and 2010/11 and shown in Table 10. The standard cost principle is used to calculate cost A and cost C2. The significant difference in cost structure of *kharif* and summer pearl millet is cost of irrigation, which is about 27% of cost

Table 10. Profitability of *kharif* and summer pearl millet under recommended resource management (average of 2009/10 and 2010/11).

	Summer		Kharif	
Items	Physical unit/ha	Value Rs/ha (% to total cost C2)	Physical unit	Value Rs/ha (% to total cost C2)
Human labor (man days)	73	7251 (23.3)	66	5888 (28.0)
Bullock labor (pair days)	3	972 (3.1)	4	981 (4.7)
Seeds (kg)	7	1225 (3.9)	6	652 (3.1)
Manures (carts)	1542	1279 (4.1)	8	2029 (9.6)
Chemical fertilizers (kg)	124	1681 (5.4)	60	824 (3.9)
Irrigation		8389 (27.0)		335 (1.6)
Insecticides/pesticides		74 (0.2)		2 (0.0)
Miscellaneous costs		2458 (7.9)		3808 (18.1)
Cost A		**23326 (75.0)**		**14517 (68.9)**
Depreciation cost		313 (1.0)		247 (1.2)
Interest on working capital		815 (2.6)		468 (2.2)
Rental value of owned land		3448 (11.1)		3587 (17.0)
Interest on owned fixed capital		358 (1.2)		325 (1.5)
Management cost		2826 (9.1)		1914 (9.1)
Cost C2		**31085 (100)**		**21057 (100)**
Yield: Main product (qt/ ha)	26.2		16.2	
Yield: By-product (qt/ha)	41.3		30.4	
Farm harvest price of main product (Rs/qt)		973		1044
Farm harvest price of by-product (Rs/qt)		220		184
Gross income: main product + by-product (Rs/ha)		**34604**		**22452**
Cost -Benefit Ratio (Cost A)		1.48		1.55
Cost -Benefit Ratio (Cost C)		1.11		1.07
Net Returns over cost A (Rs/ha)		11279		7935
Net Returns over cost C (Rs/ha)		3519		1394

Note: Cost A= all cash and kind expenses plus family labor; Cost C2= Cost A+ depreciation cost+ interest on working and fixed cost+ rental value of land+ management cost.
Source: Data collected from HOPE project, Gujarat State.

C2 in summer, while it is only 1.6% in the *kharif* season. Due to multiple irrigations, and also higher seed cost (hybrid seed purchased from private companies), cost A is higher (Rs 23,326/ ha) for summer crop compared to *kharif* crop (Rs 14,517/ha). Interestingly, under recommended resource use, the grain yield difference between *kharif* and summer pearl millet is about 62%. The net returns (gross returns-cost A) are Rs 11,279/ha in summer but only Rs 7935/ha in *kharif*. It is interesting to see that human labor constitutes about 23% of cost C2 in summer and 28% of cost C2 in *kharif*. In terms of cost A, share of human labor is 31% in summer and 40% in *kharif*, respectively. The figures indicate that the summer crop is more profitable under non-constraint resource environment.

An attempt is made to look at the profitability of pearl millet and its competing crops in the three states in northwestern India for the year 2007-08 and 2008-09 (Table 11). In all the states there is considerable fluctuation in profits across the two years and hence firm conclusions cannot be drawn. In Rajasthan, pearl millet is competitive with sorghum and maize (black gram and sesamum in 2008-09). In Haryana, pearl millet is not competitive with cotton but it is grown for its fodder value and its grain for industrial uses. Also, the cost of cultivation of pearl millet is about one half of cotton making it affordable for smallholder farmers. In Gujarat, pearl millet is competitive with groundnut and sesamum in 2008-09. Interaction with farmers revealed that summer season pearl millet competes quite well with sesamum.

Table 11. Profitability of pearl millet and competing crops in northwestern India, 2007/08 and 2008-09.

	2007-08			2008-09		
Crops	Gross Return (Rs/ha)	Cost C_2 (Rs/ha)	Benefit Cost Ratio	Gross Return (Rs/ha)	Cost C_2 (Rs/ha)	Benefit Cost Ratio
			Rajasthan			
Cotton	38,920	24,481	1.58	39,592	25,375	1.56
Sorghum	6,615	7,297	0.90	10,117	9,293	1.08
Pearl millet	9,787	8,527	1.14	10,443	10,331	1.01
Green gram	9,661	7,984	1.20	12,711	9,165	1.38
Black gram	12,956	10,676	1.21	9,074	10,723	0.84
Soyabean	20,154	14,096	1.42	18,694	15,199	1.22
Sesamum	14,139	8,442	1.67	7,942	9,384	0.84
Maize	17,534	17,729	0.98	23,399	19,810	1.18
			Haryana			
Cotton	42,125.	34,877	1.20	61,883	44,018	1.40
Pearl millet	14,002	15,803	0.88	19,642	18,716	1.04
			Gujarat			
Cotton	43,445	29,107	1.49	56,206	42,070	1.33
Pearl millet	19,581	15,593	1.25	28,231	20,836	1.35
Maize	27,084	20,039	1.35	25,132	17,655	1.42
Pigeonpea	31,227	15,315	2.03	30,489	19,551	1.55
Groundnut	36,941	23,564	1.56	36,497	30,114	1.21
Sesamum	15,621	11,327	1.37	25,565	18,817	1.35

Source: Directorate of Economics and Statistics (2011) Commission for agricultural costs and prices, Department of agriculture & cooperation, Ministry of agriculture, GOI (2010-11), GOI (2011-12).

Yield gaps between improved and local practices

The results of frontline-demonstration and on-farm trials conducted in western India for *kharif* pearl millet revealed that the responsiveness of *kharif* crop to high-cost inputs like high doses of fertilizers is low and farmers are also not willing to adopt recommended (high-cost inputs) package of practices as there is high probability of crop loss due to frequent abnormal years. Farmers opine that if there are stable returns with no crop loss, they are willing to invest more on adoption of high-cost-inputs like fertilizers. In recent years, the yield of *kharif* pearl millet has increased due to improved cultivars, but still large yield gaps exist between average yields on farmers' fields, research station and on-farm demonstrations. Late varieties have higher production potential than early varieties, but they are required to be cultivated under irrigated conditions (Table 12).

Table 12. Potential of new (*kharif*) varieties in grain and fodder yield.

Variety	Grain yield (kg/ha)	Dry fodder yield (q/ha)	% increase over local (grain)	% increase over local (fodder)
Early	2169	51	21.2	23.6
Medium	2660	79	17.6	20.2
Late	3471	136	26.8	26.8

AICPMIP (2011).

There is significant difference in crop yields from different varieties in *kharif*, for example, grain and fodder yield of early varieties is less than medium and late varieties, but they are more suitable for resource poor conditions (require less fertilizer dose NPK 40:20:0, while late varieties require 80:40:0) and escape terminal floods and hence give higher grain yield even during abnormal years. The response to supplementary irrigation is good, but farmers prefer to cultivate competing crops like guar, green gram, blackgram and sesamum when there is availability of irrigation facilities. However, there is scope for increasing the adoption rate of low-cost inputs such as (i) application of 20 kg $ZnSO_4$/ha as basal, (ii) application of atrazine @ 1.0 kg a.i. ha^{-1} as pre-emergence spray followed by atleast one hand weeding for combating weeds and thereby increasing grain and fodder yield of pearl millet to increase profitability, (iii) dust mulching and spray of 0.1% thiouorea at tillering and flowering, which helped to mitigate drought stress, reduce loss of crop and increase stability in profitability in the *kharif* season, (iv) seed treatment with neem oil 5ml/kg seed + spray of 5% NSKE (neem seed kernel extract) at 50% flowering, which was found to be an effective treatment in controlling pest attack of pearl millet (All India Coordinated Pearl Millet Improvement Project: AICPMIP 2011). The above agronomic practices are profitable both in summer and *kharif* crop. However, in case of summer pearl millet, higher fertilizer doses (NPK 90:40:0), two weedings instead of one at 25 DAS and 40 DAS and five to six irrigations recorded higher profitability (AICPMIP 2011). The economics of using these low cost inputs needs to be studied since without such data it would be difficult to introduce these on farmers' fields. The improvement in grain yield under different agronomic practices over farmers' practices is shown in Table 13.

Further, to ensure higher production and returns from pearl millet in abnormal years, different crops are recommended for intercropping with pearl millet in various states in the country. Suitable pearl millet based intercropping in northwestern India are pearl millet + cluster bean/ mothbean/

Table 13. Significance of improved package of practices over conventional practice.

Sl No.	Farmers' practice	Improved practices	% improvement in grain yield over FP	Source
1	One hoeing at 30 DAS	Hand-weeding twice at 30 and 45 DAS or pendimethalin and oxadiazon each at 1.0 kg/ha supplemented with hand-weeding once at 45 DAS	15-17 %	Ram Baldev et al. 2005
2	One hoeing at 25-30 DAS	Oxyfluorfen + hand weeding at 25 DAS	24.96 %	Deshveer and Deshveer 2005
3	Only Urea / SSP or both	10 kg Zn + RDF every year or 2.5 kg Zn + 5 t FYM ha + RDF alternate year	10-12 %	Chaube et al. 2007
4	Only Urea / SSP or both	100% RD + vermi-compost and biofertilizers treatment Or 75% RD + vermi-compost + biofertilizer	10-12 %	Satyajeet et al. 2007
5	Only Urea / SSP or both	Application of 60+40 kg/ha of N + P_2O_5 along with 10 t FYM/ha and biofertilizers	15 %	Choudhary and Gautam 2007
6	Only Urea / SSP or both	Application of 5 tons of FYM + biofertilizer (Azospirilium + PSB @ 25 g kg^{-1} each) + 60:30:30 kg NPK ha^{-1}	12-15 %	Girase et al. 2010

sesamum in Rajasthan, pearl millet + green gram/ sesamum in Haryana, pearl millet + green gram/ sesamum in Gujarat. Usually, pearl millet is rotated with sesamum, guar, moong, moth and soybean in rainfed conditions. However, farmers widely practice pearl millet+guar as mixed crop and pearl millet +pigeonpea (2:1) as inter crop. In the field survey conducted in Rajasthan, farmers ranked food for home consumption as the main reason for continuous cultivation of pearl millet followed by fodder for animal consumption, suitability to soil and climate and higher farm income in that order. Hence, there is a need for development of dual purpose varieties with good grain and fodder quality for wider adoption of varieties in northwestern India.

A list of varieties suitable for *kharif* and summer pearl millet is given in Table 14. It shows there are large yield gaps between potential and farmers average yields both in *kharif* and summer seasons. To meet this wider yield gap, the developmental pathway is adopting the IMOD concept wherein the best proven technological interventions in on-farm demonstrations need to be upscaled to larger areas. Strong policy support and extension system is necessary to achieve this transformation, which in turn will help farmers in boosting their livelihoods besides providing food and fodder security. However, the yield gaps are less in summer.

Table 14. Quality traits and grain and fodder yield potential of improved varieties.

Variety	Varietal attributes	Season	Grain yield (q/ha)	Dry fodder yield (q/ha)
HHB-67 Improved	It is slightly taller (15–30 cm), later maturing (2–3 days) and has higher grain and stover yields (5–10%) than the original HHB 67, besides being more resistant to downy mildew. Recommended for the drier parts of Rajasthan, Gujarat and Haryana. Farmers expressed a clear preference.	Kharif	25-28	60
MH 1234 (GHB 715)	Developed by Junagadh Agricultural University, Jamnagar, identified for growing in areas with scanty rainfall (less than 400 mm) in northwestern parts of Rajasthan, parts of Haryana and Gujarat. It has shown high level of downy mildew resistance and high level of drought resistance. It has a synchronous tillering, bold grain size and attractive seed color, which would help farmers in getting better market price. It also has bristled earhead, which will be helpful in reducing bird damage.	Kharif	25	65
MH 1236 (GHB 719)	Identified for growing in areas with scanty rainfall (less than 400 mm) in northwestern parts of Rajasthan, parts of Haryana and Gujarat. It also shows characteristics similar to MH 1234 hybrid.	Kharif	24	62
GHB-526	Duration of 75-80 days, medium tall, good tillering, narrow leaves with greenish white mid-rib, good exertion, yellow anthers & compact conical earheads, obviate grey brown grain.	Kharif	48-50	72
GHB-577	Duration of 70-75 days, tall, medium thick stem with basal pigmentation, semi-compact cylindrical earheads with slightly incomplete exertion and globular grains.	Kharif	32-35	70
GHB-538	Early maturing, drought tolerant, hybrid showing 27% and 23.8% grain yield superiority over MH-169 and ICMH-356, respectively. Resistant to downy mildew and tolerant to stem borer and shootfly.	Kharif	27-30	42

Continued

Table 14 *continued.*

Variety	Varietal attributes	Season	Grain yield (q/ha)	Dry fodder yield (q/ha)
GHB-744	Early maturing (75-80 days)	Kharif	30-32	70
9444	Maturing in 80-85 days, very high grain & fodder yield, highly adaptable, tolerant to heat & moisture stress, tolerant to downy mildew, tall dual purpose hybrid	Kharif	40-45	65
MSH 155 (86 M 52)	Identified for growing under irrigated conditions in pearl millet growing areas. It has broad leaves, wavy leaf margins and smooth surface, is tall, has stay green fodder quality, good standabilty and high yield potential, tolerance to DM, very good grain size & color like desi pearl millet, matures in 80 to 85 days	Summer	46	65
GHB-316	Higher grain & fodder yield during summer. Acceptable ear shape and plant type. Good quality grain.	Summer	43-45	75
GHB-558	Recommended for summer season. Average yield higher by 16.9% and 22.3% over MH-169 and GHB-183, respectively.	Summer	47-48	76
GHB-538	It is early maturity and has shown temperature insensitivity for seed set under summer and pre-rabi seasons. Superior in grain yield under summer season over MH-169 (17.7%) in north Gujarat and Saurashtra and under pre-rabi condition over GHB-526 (8.7%) in Saurashtra. High level of resistance to downy mildew and pests of pearl millet. The hybrid GHB-538 is endorsed for cultivation for summer/pre-rabi pearl millet growing areas of north Gujarat and Saurashtra region.	Summer	48-50	60
9444 G	Tall dual purpose hybrid, maturing in 80-85 days, very high grain & fodder yield, highly adaptable, tolerant to heat & moisture stress, tolerant to downy mildew, good tolerance against termite	Summer	45-46	89

Source: AICPMIP (2011).

Conclusion and Recommendation

The paper examines the existing status of *kharif* and summer pearl millet in the background of declining food demand for its grain and growing alternative demand from poultry, cattle feed industry and alcohol industry. To meet the demand from alternate industries such as feed and brewery industries, it is important to decrease the cost of production to make it competitive with maize, sorghum and broken rice. With this background, the paper examines the ways to increase production both in *kharif* and summer crop with focus on cost of production and profitability of improved technology. The production structure (input-output structure) and competitive environment of both *kharif* and summer crops is different. *Kharif* pearl millet is cultivated under rainfed conditions with low-input-low-output management, while summer pearl millet is cultivated under high-input-high-output management.

Even though *kharif* pearl millet yields are low, it still occupies a large area in northwestern India. Most of the *kharif* harvest is used for domestic purposes like food, feed, and in alternative uses like alcohol and poultry feed industries. In view of the importance of *kharif* pearl millet in fulfilling food–feed security and its alternative uses, ways to enhance its yields should be identified and adopted widely. As it is mostly grown under rainfed conditions, farmers follow different risk management strategies to cope with frequent droughts during crop growth period. In Rajasthan, the popular variety HHB-67 Improved (early maturing cultivar) performed well during abnormal years of rain, even though its performance is less than high yielding private hybrid seeds. Realizing the high probability of abnormal years, farmers widely grow HHB-67. There is severe shortage of certified seeds in the *kharif* season and the adoption of publicly-released varieties especially for the *kharif* season through large scale seed production and distribution by State Seed Corporations in Public-Private-Partnership mode needs to be promoted.

Summer pearl millet area is only 25% of total pearl millet area, but contributes 44% to the production in Gujarat. For summer pearl millet, the entire grain produced is marketed immediately after harvest. Its grain is consumed domestically for food particularly in the lean season in areas where summer pearl millet is not grown and the second and third grade grain is extensively used by the poultry and alcohol industries. It is a preferred grain for export to the Gulf countries for poultry feed and other uses. Thus, the summer crop is mainly cultivated as a commercial crop. In terms of cost composition, expenditure on irrigation and seed is higher in summer pearl millet than *kharif*, but profitability is also high due to doubling of yields of the summer crop. There is thus a good scope for expanding area under summer pearl millet given its short duration (March–May) and as no other crop is suitable to be grown given the high temperatures prevailing during this period. However, there is a need for sufficient irrigation facilities to cultivate the crop as also suitable cultivars that could further reduce the per unit cost of production.

For both *kharif* and summer pearl millet, dual purpose varieties are a must as this is an important source of animal feed contributing to feed security in the marginal and dry areas. Besides dual purpose varieties, development and wider adoption of varieties suitable for non-food uses (feed, fodder and alcohol industry) need to be given priority to meet future demand growth.

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