Pearl millet as a postrainy cool season crop: case studies from Gujarat and Maharashtra, India

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Abstract

Case studies of winter season (*rabi*) pearl millet cultivation conducted in 2007–09 in Junagadh, Gujarat, and Jalgaon, Maharashtra states of India showed increasing interest of farmers in this cropping system because of the importance of the crop in sustaining farmers' household requirements of nutritious food and fodder. A major constraint faced by farmers in these areas is the changing growing conditions such as low temperature of 10–15°C, which reduces plant growth, delays maturity, and leads to a reduced biomass yield. The existence of genetic variation for this trait can effectively address this issue. The farmers' practice of adjusting sowing time largely overcomes the problem of poor seed setting at low temperature. However, genetic improvement of this trait is needed to allow flexible sowing time. Employing other cultural management practices, such as crop rotation juxtaposed with the adherence to a cropping calendar of pearl millet, yields economic benefits to farmers. Results showed that winter season pearl millet cultivation resulted in a benefit-cost ratio of 3.62 in Junagadh and 3.12 in Jalgaon. These attributes of pearl millet combined with high water-use efficiency under water limiting environments make it a potential replacement crop in the global scenario of climate change with bright prospect for developing hybrids suited to winter season environments.

Introduction

Pearl millet (*Pennisetum glaucum*) is a nutritious cereal grown on about 10 million ha in India, which is the largest producer of this crop in the world. It ranks third after wheat (*Triticum aestivum*) and rice (*Oryza sativa*) in area in India (GOI 2008). It is basically cultivated as a rainfed crop, largely under marginal environment and with no or little external inputs where grain yields vary mostly between 400 and 900 kg ha^{-1}. It is also grown on a limited scale (<500,000 ha), as an irrigated summer crop with 80–100 kg ha^{-1} applied nitrogen, in parts of Gujarat, Rajasthan and Uttar Pradesh. Under such conditions, hybrids of 80–85 days maturity give 4–5 t ha^{-1} of grain yield. In parts of Gujarat, farmers report up to 6 t ha^{-1} of grain yield, indicating highly input responsive nature of this crop. High grain and fodder yield of better quality, and greater water-use efficiency combined with tolerance to heat during flowering and grain development (air temperature during flowering can exceed 42°C) have been mentioned by farmers as reasons for cultivating pearl millet in the summer season. There are indications that pearl millet area under summer cultivation has been on the rise in Gujarat and Uttar Pradesh, and further increase is possible if a wider range of hybrids tolerant to higher air temperature during the flowering period can be developed.

In Junagadh district of Gujarat and Jalgaon district of Maharashtra, pearl millet has recently become popular as a postrainy (*rabi*) cool season crop. Hard data on the area under *rabi* season are not available. This paper presents the results of a preliminary case study of *rabi* season pearl millet cultivation in Junagadh and Jalgaon districts.

Pearl millet in farm holdings

This study conducted in 2007–08 adopted an earlier survey instrument used in 2003 where agronomic and breeding-related questions are key aspects with the addition of socioeconomic parameters like cost and return analysis, varietal preferences, and other observations related to quality and performance of varieties. In Gujarat, the study conducted in Junagadh district in 2007 provided for the validation of results of an earlier survey as well as elicitation of new insights.

Old and new farmer-respondents from the same district of Junagadh provided the data on farmers' behavior to innovations like the introduction of hybrids. Data were obtained from four blocks of Junagadh (Talala, Patan-Veraval, Malia and Keshod) with varying landholdings. The average farm size planted with pearl millet in this area was 0.43 ha. In Maharashtra, three blocks (Chopda, Dharangaon and Bhadgaon) in the district of Jalgaon were included in this study. Farmers in this district have relatively larger farm holdings (0.8–9 ha) with an average of 3.6 ha compared to those in Junagadh. Pearl millet cultivation was on an average farm size of 1 ha, which was more than twice of that in Junagadh, but almost the same with respect to the percentage of the farmers' total land area valued at 30%. In both districts, the findings revealed the importance of pearl millet among the farmer-respondents as they cultivate 30% of the land with pearl millet in spite of the other popular high-value crops such as wheat, coriander (*Coriandrum sativum*), cumin (*Cuminum cyminum*); besides chickpea (*Cicer arietinum*) in Junagadh, and chickpea, vegetables, groundnut (*Arachis hypogaea*) and maize (*Zea mays*) in Jalgaon. In Jalgaon, the preference for pearl millet was not only because of its short duration but also due to the need to satisfy the demand for food since pearl millet is a staple in this area.

Growing conditions and crop growth

Pearl millet is a warm season cereal. Pearl millet growth rate is proportional to solar radiation interception and the plant development rate is proportional to the accumulation of degree-days above a base temperature of 10°C (Ong and Monteith 1985). Plant development severely slows down leading to reduced biomass yield when the minimum temperature is below 15°C. *Rabi* season crop is planted in September–October in Junagadh and October–November in Jalgaon. Pearl millet planted at those times will encounter 10–15°C of the minimum temperature during most of the crop growth period until harvesting in January–February (Figs. 1 and 2). These temperatures are not congenial for rapid crop growth and development, delaying the maturity and reducing the biomass yield; however, genetic variation in pearl millet may exist for *rabi* season adaptation. A major problem expressed by some farmers, especially those who had late sowing, was poor seed setting due to low temperature (Fig. 3). Also, *rabi* season cultivation may encounter new challenges. There were no significant pests and diseases of pearl millet. However, farmer respondents mentioned pests such as aphids and grasshoppers, and diseases such as rust affecting the crop. The prevalence of these biotic constraints would need to be assessed and systematically monitored.

Crop rotation

Farmers of the study area cultivated different crops in different seasons in the same area following a certain sequence. This practice, according to them, improved soil fertility and is also a way to maximize the use of the

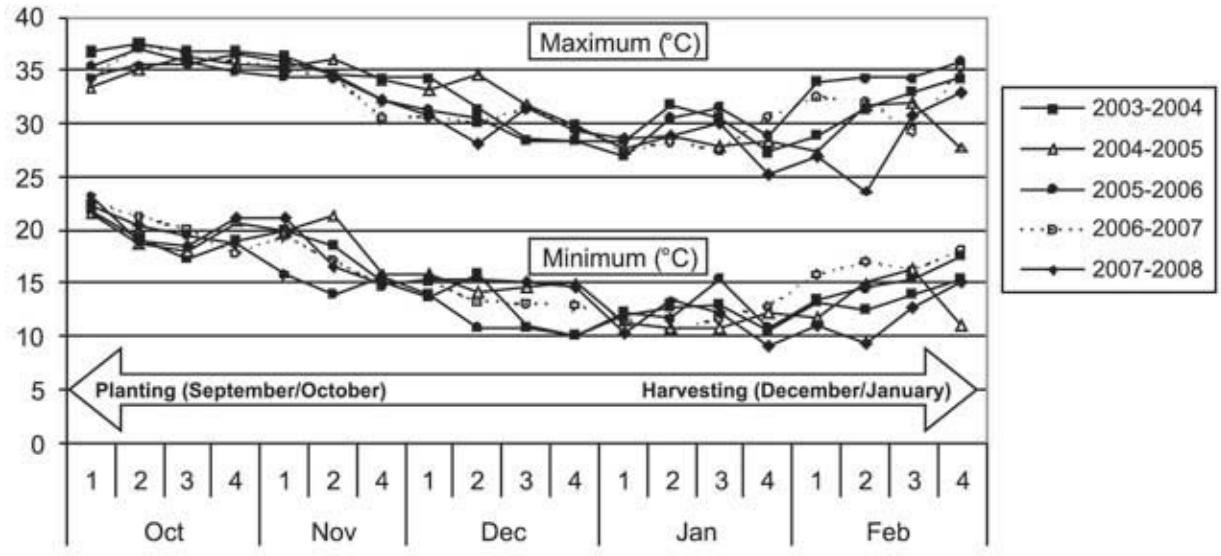

Figure 1. Weekly minimum and maximum temperatures during pearl millet *rabi* season (2003–08) in Junagadh, Gujarat, India.

leftover nutrients in the soil. In Junagadh, farmer-respondents regarded wheat as the best crop for *rabi* season followed by either groundnut or sugarcane (*Saccharum officinarum*). However, the diminishing soil moisture due to scarce rainfall accounts for the shift towards pearl millet, which grows well under such conditions. Equally important reasons are short maturity (80–90 days), lesser input requirements like fertilizers, suitability as an intercrop with plantation crops like mango (*Mangifera indica*) and coconut (*Cocos nucifera*) and good stover yield. Farmers of Jalgaon have a preference for wheat but recently, more farmers are slowly shifting to pearl millet due to lower and erratic rainfall. A couple of farmers mentioned sorghum (*Sorghum bicolor*), tissue-culture banana (*Musa* sp) and onion (*Allium cepa*) as alternative crops.

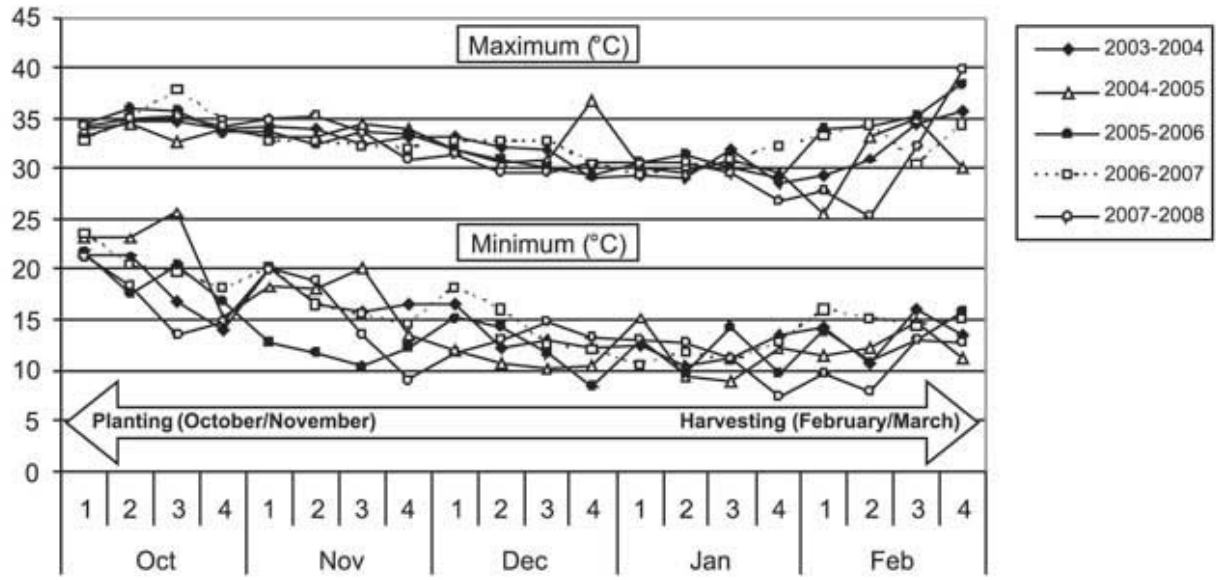

Figure 2. Weekly minimum and maximum temperatures during pearl millet *rabi* season (2003–08) in Jalgaon, Maharashtra, India.

Figure 3. Bumper growth of a pearl millet hybrid in *rabi* season where seed set improvement needs attention.

Cropping calendar

Rabi pearl millet in both districts is planted as a sole crop. Moreover, pearl millet is regarded both as a main crop and secondary crop (Figs. 4 and 5). The meaning of a main crop is that the larger area is cultivated with that crop. A secondary crop, therefore, is smaller area-wise with respect to the main crop. A factor that contributes to the practice of crop diversification is farmers' concern for ensuring food security owing to their small landholdings, more so in Junagadh.

Farmers in Junagadh who consider pearl millet as a main crop, cultivate chickpea (25%), sugarcane (12.5%), vegetables (25%), maize (12.5%) and fodder crops (37.5%) like sorghum and lucerne (*Medicago sativa*) as secondary crops. Planting dates for *rabi* season crop starts in late September to October. When pearl millet is regarded as a secondary crop, main crops could be either wheat (37.5%), plantation crops (37.5%) or herbs (12.5%). Legumes such as groundnut, green gram (*Vigna radiata;* mung bean) and black gram (*Vigna mungo*) are rotated before and after *rabi* pearl millet cultivation (Fig. 4). In the earlier survey conducted in 2003, groundnut was highly preferred with 87.5% of farmers, but in the survey made in 2007–08, the preference for this crop declined to 50%.

In Jalgaon, pearl millet is the major secondary crop for the *rabi* season (67%), followed by chickpea and wheat (33% each), sorghum and maize (20% each), vegetables and pigeonpea (*Cajanus cajan*) (13% each) and groundnut (7%). However, pearl millet as a main crop is being increasingly adopted because of its potential in utilizing the soil moisture to the fullest before the fields are left fallow for about 1–2 months in preparation for cotton (*Gossypium* sp). It is a common practice among the farmers of this area to have early and late planting of pearl millet. The earliest planting time is in the last week of October to last week of November and harvesting commences in the last week of February to 2nd week of March (Fig. 5). Interestingly, those who regarded pearl millet as a main crop in both *rabi* and summer seasons were growing ICTP 8203, a popular ICRISAT-bred variety released in 1988. According to Nirmal Seeds Pvt Ltd, there has been a growing demand for this cultivar for the past five years because of its suitability to less endowed areas and harsh socioeconomic environments.

Although pearl millet is known to require high temperature (Khairwal et al. 1999) for successful growth, the potential for improving the productivity of pearl millet cultivation during *rabi* season is promising. The low temperatures of 10–15°C during *rabi* growing season as shown in Figures 1 and 2 must have affected grain yield. As related by farmer-respondents, the early occurrence of low temperatures (during the reproductive phase) led to poor seed setting. The lowest recorded temperature in 2007–08 was 9.1°C in Junagadh and 7.1°C in Jalgaon. However, low temperatures of 21/16°C during the vegetative stage can increase basal tillering, which in turn results in higher total grain yield per plant (Fussell et al. 1980).

With the flowering stage taking place around 40–45 days after planting, seed setting or the entire reproductive phase was definitely affected by the occurrence of low temperatures. While the crop does best in hot environments, the possibility of producing in cooler temperature can take place as indicated by the crop's performance in the two study sites. However, for proper growth and high yields under the changing dynamics of climate change, breeding of cultivars to address the intensity of stress brought by fluctuations in temperature is imperative.

Popular cultivars

The penchant for hybrid materials was explicitly mentioned by the farmer-respondents. The cultivation of hybrids was regarded by farmers as better option giving a more secure yield. This has been the norm in the study areas, which explains the desire for new types of planting material.

The surveys conducted in 2003 and 2007–08 in Junagadh, revealed the same findings (ie, preference for hybrid seed). Nandi 3, Sona 3 and Proagro 9444 were the most popular and the most widely grown cultivars (Table 1). Sona 3 was planted three years back as revealed by the earlier survey while Proagro 9444 is a more recent introduction yet, already raved by farmers because of

Table 1. Pearl millet cultivars grown by respondents in Junagadh and Jalgaon.

Cultivars	Seed company	No. of farmers
Junagadh		
Nandi 3	Nandi Seeds Corp	5
Proagro 9444	Proagro Seed Company Pvt Ltd	2
Sona 3	Sona Seeds Pvt Ltd	1
Jalgaon		
Nirmal 40	Nirmal Seeds Pvt Ltd	5
ICTP 8303	National Seeds Coporation Nirmal Seeds Pvt Ltd	5
Nirmal 1579	Nirmal Seeds Pvt Ltd	3
Proagro 9330	Proagro Seeds Company Pvt Ltd	2
MLBH 308	Mahendra Pvt Seeds Ltd	2
Pioneer 8632	Pioneer Seed Company Ltd	2
Proagro 9332	Proagro Seed Company Pvt Ltd	1
Maulee	Maulee Seeds Pvt Ltd	1

Rainy season (May–September)	
	groundnut, green gram and black gram
***Rabi* season** (late September/October)	
Main crop	wheat, pearl millet, plantation crops and herbs
Secondary crop	pearl millet, chickpea, groundnut, sugarcane, garlic, vegetables, maize and fodder crops (ie, sorghum and lucerne)
Summer season (March–April)	
	groundnut, green gram and black gram

Figure 4. Cropping pattern in Junagadh, Gujarat, India.

Rainy season (May–September/early October)	
Main crop	cotton and maize
Secondary crop	groundnut, green gram, black gram, sorghum, maize, cotton, sugarcane and pearl millet
***Rabi* season** (October/November–February/March)	
Main crop	wheat, pearl millet, banana and groundnut
Secondary crop	chickpea, wheat, pearl millet, sorghum, maize, vegetables, groundnut and pigeonpea
Summer season (March–April)	
	Fallow period

Figure 5. Cropping pattern in Jalgaon, Maharashtra, India.

good tillering, uniform panicles and good yield, which are some of the varietal qualities desired. All the farmer-respondents preferred pearl millet cultivars with the following traits: medium duration (80–90 days) because of the limited soil moisture and no disruption in the cultivation of their main crops, especially groundnut; medium height of 150–180 cm for reasonable yield and easy bird scaring to protect from bird damage; medium-bold grains with gray-brown to dark gray color; and high yield.

Relatively larger number of cultivars was grown in Jalgaon with Nirmal 40 and Nirmal 1579 as the two most popular hybrids. The ICTP 8203 growers were mostly farmer cooperators of a seed company, who collaborate for seed production. This was also validated by key staff of the seed company where the demand for ICTP 8203 is high not only in Maharashtra but also in other states like Rajasthan and Uttar Pradesh.

Economics of production

Yields in both districts were comparable. In Jungadh, yield ranged from 3,000 kg ha^{-1} to 4,500 kg ha^{-1}, with an average of 4,124 kg ha^{-1} (Table 2). This yield is much higher compared to 1,344 kg ha^{-1} in 2001 as reported by the Main Pearl Millet Research Station in Jamnagar, Gujarat (http://www.jau.in/res_millet.asp verified in October 2008). Most recent data (verification in July 2009) from the same research station revealed grain yield of 3500–4,000 kg ha^{-1}, which is comparable with the result of this study. On the other hand, stover yield from this crop is valued significantly by farm households because of their livestock averaging two bullocks and two cows per household. Farmer-respondents reported an average stover yield of about 7,875 kg ha^{-1}, almost twice as much as the grain yield. *Rabi* season pearl millet cultivation, according to farmer-respondents, results in 10–25% higher grain yield than the rainy season crop.

In Jalgaon, the yield ranged from 2,000 kg ha^{-1} to 5,000 kg ha^{-1}, with an average yield of 3,700 kg ha^{-1} (Table 2). In terms of stover yield, data from Jalgaon are significantly lower (about one-sixth of that in Junagadh). Farmers in this part of India do value the stover but pearl millet stover is not very popular because they grow other fodder crops like sorghum purposely for stover.

With good cultural management practices, the average income from cultivating *rabi* season pearl millet in Junagadh is approximately Rs 30,466 ha^{-1} with a benefit-cost ratio of 3.62, while in Jalgaon, it was Rs 25,163 ha^{-1} with a benefit-cost ratio of 3.12 (Table 2). Farm inputs such as farmyard manure and inorganic fertilizer like urea, are important for the *rabi* season pearl millet. However, these are applied to the preceding crop and farmers claimed that the residual effects of these fertilizers account for better yields of pearl millet.

Table 2. Economic benefit of *rabi* pearl millet production per hectare in two districts in India.

	Junagadh (n=8)[1]		Jalgaon (n=15)[1]	
Production variable	Range	Average	Range	Average
Total size of landholdings (ha)	0.6–2.5	2.07	0.8–9.0	3.61
Pearl millet area (ha)	0.2–0.5	0.43	0.4–3.2	1.05
Seed used (kg)	6–18	10.56	3.75–4.50	3.85
Grain yield (kg)	3,000–4,500	4,124	2,000–5,000	3,700
Grain price (Rs kg^{-1})	7.50–9.50	8.25	7–10	8.60
Grain gross income (Rs)	25,500–42,750	33,875	16,875–42,500	31,842
Stover yield (kg)	3,000–9,000	7,875	1,000–2,100	1,380
Stover gross income (Rs)	3,000–9,000	7,875	1,000–2,100	1,380
Total gross income (Rs)	31,500–51,750	41,750	18,000–44,600	33,222
Cost of seed (Rs)	800–3,600	1,643	525–675	586
Cost of fertilizer (Rs)	600–1,200	1,000	1,250–3,000	2,200
Cost of farmyard manure[2] (Rs)	600–8,000	3,000	–	–
Cost of land preparation (Rs)	1,000–1,800	1,575	1,250–3,000	2,183
Cost of hoeing, weeding, etc (Rs)	800–2,000	1,331	900–1,250	1,063
Cost of harvesting and threshing (Rs)	1,500–3,000	1,883	1,200–2,500	1,860
Total production cost (Rs)	6,500–13,950	9,242	5,425–9,838	8,059
Net income (Rs)[3]	22,400–44,850	30,466	11,850 – 35,213	25,163
Benefit-cost ratio	2.06–6.5	3.62	1.90–4.90	3.12

1. Number of farmers.
2. Applied before the *rabi* season.
3. 1 US$ = Rs 47.50.

Additional plant nutrition has been proven to increase yield of pearl millet and also there is an increase in the water-use efficiency of about 84% as a result of fertilizer application (Felch 2007). A point of concern in the production system of Junagadh is the high amount of seeding rate estimated at 10.56 kg ha^{-1}, which is almost three times the rate in Jalgaon (3.85 kg ha^{-1}). This accounts for the tripling of seed cost incurred by farmers in Junagadh as compared to those in Jalgaon. Input use specifically of fertilizer is higher in Jalgaon. This is not surprising because farmers who are into the seed production enterprise require fertilizers to ensure successful production of seeds.

Other costs like land preparation was slightly higher in Jalgaon than in Junagadh. Other costs of farm operations like hoeing, weeding, thinning and harvesting did not vary significantly in both areas. A farm operation not factored into economic analysis was the cost of labor for chasing away birds that cause much damage to pearl millet fields. The estimated damage could fetch about 5 to 10% loss in grain yield (http://www. jeffersoninstitute. org/pubs/millet.shtml verified in December 2008). Household labor was mostly utilized for chasing away birds and since this is not a whole day job, farmer-respondents do not factor it into input cost. But it is indeed time consuming during the grain-filling stage.

Conclusion

The *rabi* season pearl millet cultivation is very important for farm households in parts of Junagadh and Jalgaon because this provides a major source of their food requirement. Pearl millet is still the staple food of most people in this area. Its fodder or stover is a good resource for their livestock, which in turn determines the availability of animal protein – milk. While the area devoted to pearl millet cultivation is relatively small, its role in the household food security is remarkable to deserve the attention for improving its production system as pearl millet is high in calories, phosphorus and iron.

In Junagadh, the seeding rate is almost 11 kg ha^{-1} compared to recommended seeding rate of about 3 kg ha^{-1} and 4.5 kg ha^{-1} (http://www.jeffersoninstitute.org/pubs/millet.shtml verified in June 2009). Farmer-respondents' behavior on seeding rate reveals the extreme value of ensuring success at whatever cost for pearl millet cultivation, right at the beginning. According to the farmer-respondents, they will not hesitate to spend more on seeds because thinning can be done rather than having to face with the situation of poor seed germination which can jeopardize the crop's productivity. It appears that farmer-respondents are unable to take risk on matters central to their livelihood security like its direct consumption as food or indirectly use as fodder for their dairy and draft animals. This is a case in point showing the need to understand the entire production-utilization chain covering the pre-, main- and post-production phases before any recommendation can be made. Those from the R&D group, as suggested, need to be more imaginative in developing technologies not only with respect to the physical environment but also farmers' behavior like 'trade-offs farmers calculate between grain and fodder, between yield and yield stability, and between input responsiveness and productivity under low-input conditions' (http://www.fao.org/docrep/W1808E/w1808e0h.htm verified in June 2009).

With respect to the economics of production, there is a good potential as shown by the high benefit-cost ratio. To date, farmers seem to be just concerned with their food requirements which explains the small area planted with pearl millet. Given the situation of the impending effects of climate change where rainfall is getting increasingly erratic and scarce, traditional crops like pearl millet that require less water but are rich in nutrients will play a significant role in ensuring farm households' food security. Considering the variability for *rabi* season adaptation, prospects for breeding pearl millet hybrids specifically suited to *rabi* season environments (ie, increased biomass and grain yield under low temperature regime) are good.

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