Sorghum and Pearl Millet Economy of India
Future Outlook and Options

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Coarse cereals such as pearl millet and sorghum, the hardiest and least risky cereals, are mainly grown in India's arid and semi-arid regions. These crops possess high nutritive and fodder value and are primarily consumed by their producers. On the supply side, there has been a large shift in the area under cultivation to rice and wheat and other commercial crops. On the demand side, the distribution of rice and wheat at subsidised prices through the public distribution system has led to a fall in the consumption of sorghum and millets. The decline in cultivated area could result in a problem for the livestock sector in many regions. It is crucial that the sorghum and millet sector be supported by strong government policies and programmes for food, fodder, and better nutrition through value addition and demand creation.

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More than 60% of the cultivated area in India is in arid and semi-arid regions, characterised by long dry seasons, inadequate and unpredictable rainfall, and infertile and fragile soils. These regions provide around 40% of the food produced (Gulati and Kelley 2000). Farmers exposed to harsh agro-climatic conditions cultivate shallow and poor soils receiving low and erratic rainfall below 600 mm. Recurrent droughts, coupled with frequent dry spells, further exacerbate the situation. In the last few decades, these regions have been facing a shrinking natural resource base and land degradation, resulting in low productivity in the crop and livestock sectors. This has contributed to increased poverty, malnutrition, and indebtedness of smallholder families.

In arid and semi-arid conditions, the cropping choice is restricted due to moisture stress, low soil fertility, poor and saline soils, and lack of assured sources of irrigation. Dryland cereals such as sorghum and millet are hardy crops that thrive in adverse agro-ecological situations, making them less risky for producers. Sorghum and millets occupy a prime place in smallholder farming systems in arid and semi-arid regions, providing employment, income, food for consumption, and feed for livestock. At the same time, excessive dependence on rice and wheat for food self-sufficiency has not only made food security fragile, but also shrunk the diversity of the food basket because they are resource intensive and inefficient in terms of crop output-moisture response. To alleviate this problem and make food more nutritional, healthy, and affordable, coarse cereals (now renamed nutritious cereals) such as pearl millet and sorghum deserve to be promoted, especially given that climate change is upon us.

Background

In India, pearl millet and sorghum are cultivated as dual-purpose crops in more than 9.3 million hectares (ha) and 8.3 million ha respectively, ranking them third and fourth among all cereals (Yadav et al 2011). Sorghum is widely cultivated during the rainy and post-rainy seasons in central and western Maharashtra, northern Karnataka, Andhra Pradesh, and Tamil Nadu, while pearl millet is produced in Rajasthan, Gujarat, Maharashtra, Uttar Pradesh, and Haryana. Besides grain, millet and sorghum are an important feed for livestock, especially in the dry months when other feed resources are in short supply. The sorghum grain produced during the post-rainy season (rabi) is from local and improved landraces of

superior quality (bold, white, and with a sweeter taste) and hence preferred for human consumption. In contrast, the sorghum produced in the rainy season (kharif) is from hybrids, with poor grain quality, and is less preferred for human consumption. About 50% of the kharif produce goes into alternative uses such as poultry feed, alcohol, and animal feed, while rabi sorghum is exclusively used as food (Parthasarathy Rao et al 2010). Pearl millet, on the other hand, apart from being used as a staple food, is also used as poultry and animal feed, and for the production of alcohol and health foods.

In the rainfed regions of the country where sorghum and millets are grown, they form the staple diet of a majority of poor smallholders and poor consumers. The advantages of growing these crops are that they need less external input, are drought tolerant, sturdy, short to medium duration, low labour utilising, resistant to pests and diseases, and meet food, nutrition, and fodder requirements. Second, millets are c4 crops having carbon fixing properties (that is, they are climate-change compliant). Given moisture stress, millets are the best alternatives for extreme weather conditions and are well suited to drought-prone regions. Third, an important feature of sorghum and millets is their nutritional quality. They are the richest sources of nutrition, especially iron, calcium, and zinc, among cereals and can provide all the nutrients at the least cost to the poor compared to wheat and rice (Parthasarathy Rao et al 2006). Fourth, the crop residue of sorghum and pearl millet forms an important component of feed for livestock (Parthasarathy and Hall 2003). Despite these advantages, a lack of economic incentives in the face of declining food consumption of these crops has relegated them to the status of inferior crops.

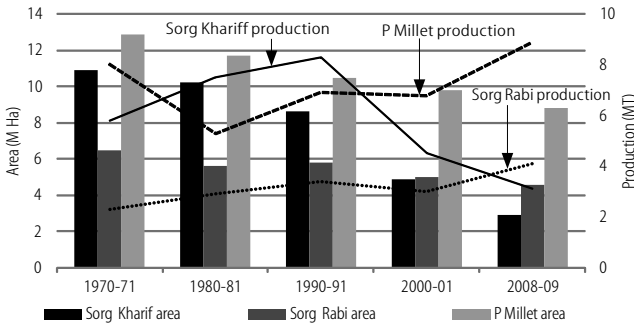
Focus of Study

Considering the vital role of coarse cereals in the food basket and livestock economy, it is critical to have an economic analysis, which leads to policy steps aimed at promoting these crops. This paper focuses on the pearl millet and sorghum economy, analysing their growth and consumption trends, identifying the structural constraints in enhancing productivity growth, and identifying areas for future investment, markets, and policy options.

Area, Production, and Productivity Trends

The total sorghum area (kharif and rabi seasons) has shrunk over time from 17.4 million ha in 1970-71 to 7.5 million ha in 2008-09, a 56% decline over the past three decades. The growth rate has been negative at -1.23% per annum. The kharif area dipped at a faster rate (70%) than the rabi area (32%) between 1970 and 2009 (Figure 1). This was mainly due to a diversion of kharif sorghum areas to crops such as sunflower, maize, groundnut, and pulses. Further, sorghum has been replaced by commercial crops such as sugar cane, cotton, onion, and maize due to improved access to irrigation in some areas and increases in their prices owing to increasing consumer demand. Sorghum cultivation is concentrated in Maharashtra, Karnataka and Andhra Pradesh, which together account for

Figure 1: Area and Production of Sorghum and Pearl Millet in India
(1970-71 to 2008-09)



Source: *Economic Survey*, GOI (2010).

75% of the national area. Both for rainy and post-rainy season sorghum cultivation, Maharashtra is the dominant growing state, accounting for 34% of kharif area and 70% of the post-rainy season sorghum during 2010-11, while Rajasthan with 57% of the area dominated pearl millet cultivation.

To understand the decline in area at a disaggregated district level, the spatial distribution of sorghum (rainy and post-rainy) in Maharashtra and Karnataka, and that of pearl millet in Rajasthan, Gujarat, and Haryana is classified under five different categories in Appendix 1 (p 81). For periods between 1970-80 and 1990-2000, there was a shift in the decadal average of rainy season sorghum area with districts in the very high category (> 3,00,000 ha) moving to the high category (> 2,50,000 ha). The districts in the low category (50,000-1,00,000 ha) moved to the very low category (< 50,000 ha). Similarly, for post-rainy season sorghum, the districts in the very high category (> 7,00,000 ha) shifted to the high category (5,00,000-7,00,000 ha). In the case of pearl millet, though the area remained more or less similar between the two periods, districts of Rajasthan in the high category (5,00,000-8,50,000 ha) moved to the medium category (1,50,000-5,00,000 ha). Similar shifts were evident in districts of Gujarat and Haryana from the low (50,000-1,50,000 ha) to the very low categories (< 50,000 ha).

Despite a sharp decline in area, the production of kharif sorghum increased till 1990 due to the use of hybrids and improved cultivars, and gradually decreased after that owing to a decline in area. After the 1990s, the increase in yield also slowed down. Overall rabi sorghum production increased by 83% from 1971 to 2009, while kharif sorghum production declined by 52%. Thus, currently, 55% of the area is under rabi sorghum compared to 35% in the 1970s. In the case of pearl millet, the area and production increased till the 1970s and declined during the 1980s due to downy mildew epidemics (Pray and Nagarajan 2009a). After the 1980s, though there was a marginal decline in the area under pearl millet, accelerated productivity sustained production.

Factors Responsible for Decline in Area under Millets

The focus of the green revolution on high-yielding and high-input utilisation crops such as wheat and rice to meet the demands of food security resulted in policies favouring their cultivation. Further, these crops received research, extension,

and market support. Thus, on the supply side, there was a shift in area under cultivation from coarse cereals to rice and wheat even in rainfed areas. On the demand side, the distribution of rice and wheat through the public distribution system (PDS) at subsidised prices contributed to a decline in the consumption of sorghum and millets.

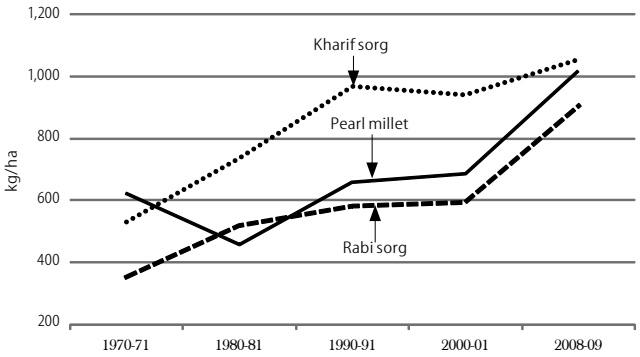
Poor policy support for millets on the one hand and favourable policies for the cultivation of oilseeds such as sunflower and soybeans and cash crops such as cotton became more profitable, driven by yield increases and higher prices spurred by growing consumer demand. This has resulted in serious imbalances in the demand and supply of various agricultural commodities in the country

On the consumption side, in urban areas, an increase in incomes, change in consumer tastes and preferences, both husbands and wives having jobs, the advent of fast food chains and ready-to-eat food products, the penetration of diversified value-added products from rice and wheat, and the ease of preparation and short cooking time for them have resulted in their increased consumption. In contrast, longer cooking times, difficulty in preparation, and the lack of value addition and value-added products contributed to a decline in the consumption of sorghum and millets. A technology mission on oilseeds and pulses to promote pulses and oilseeds as development initiatives of governments further dampened farmers' interest in cultivating millet. Extension efforts towards the cultivation of millets were relegated, and coupled with market failure, this led to a failure to capture the nutritive value of millets

Change in Area, Production, and Productivity Trends

With the green revolution, the productivity of sorghum and pearl millet increased appreciably. In most of the producing states, the trends in area, production, and productivity of sorghum and pearl millet have witnessed three waves of change. The first wave was in the pre-green revolution period (1950s to 1960s), the second in the green revolution period (1970s to 1980s), and the third in the post-green revolution period (after the 1990s). In the pre-green revolution period, traditional varieties were grown, and the growth in output was driven by an expansion in area. In the green revolution period, there was an appreciable increase in productivity (40%) due to high-yielding varieties and hybrids, the intensive use of chemical fertilisers, and an improved package of practices. However, owing to frequent outbreaks of downy mildew, the yield of millet stagnated during the early 1980s, and rebounded in the mid-1980s with the release of varieties that were resistant to fungus, with the assistance of the International Crops Research Institute for the Semi-Arid-Tropics (ICRISAT) (Pray and Nagarajan 2009a). Thus, in the second wave of change, the growth in output was mainly productivity-led due to technical changes and access to markets. The third period has been marked by the release of varieties with value-added attributes such as resistance to pests and diseases, and drought and heat tolerance. In this period, the area under pearl millet declined but its productivity increased

Figure 2: Productivity Trends of Sorghum (Kharif and Rabi) and Pearl Millet in India from 1970-71 to 2008-09 (kg/ha)



at a higher rate than sorghum. Nevertheless, the production levels of both grains were stable.

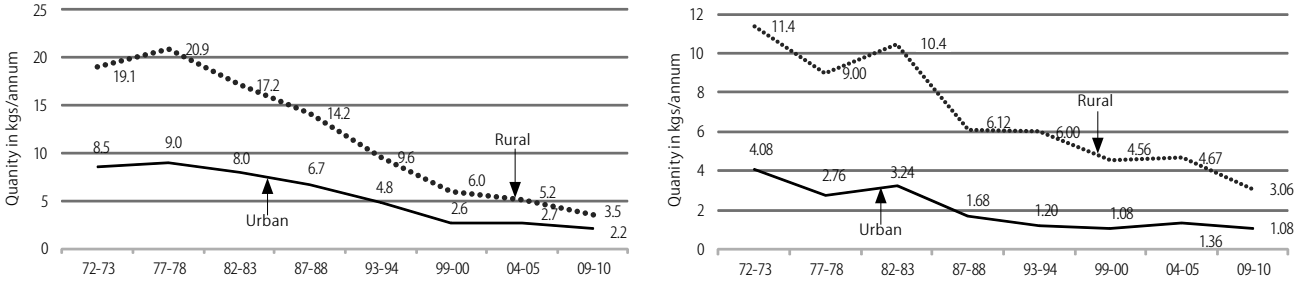
Though the productivity in kharif sorghum recorded a high compound growth rate of 2.5% per annum, there has been a wide productivity differential between the kharif and rabi crops. This is due to the non-availability of improved cultivars for rabi sorghum and its cultivation in residual soil moisture. Improved varieties occupy only 25% to 30% of the area under rabi sorghum cultivation. An ex ante analysis of improved technologies indicates that the additional cost of replacing the local variety with an improved variety and improved management practices is Rs 3,413 per ha, yielding a net gain of Rs 6,088 per ha, with an incremental returns to cost ratio of 1.78. The incremental income is Rs 2,675. Similarly, the additional cost associated with replacing a variety and improving management practices is Rs 4,083 per ha, with an incremental cost to return ratio of 3.51. With supplementary irrigation, the net gain increased for the private institutions that helped breed varieties resistant to biotic and abiotic factors.

Using ICRISAT germplasm and breeding materials, 242 sorghum and 163 pearl millet varieties/hybrids had been released by the National Agricultural Research System (NARS) as of December 2010. The research institutes focused on breeding varieties that are resistant to pests and diseases, while seed production was carried out by both the public and private sectors. After the 1990s, favourable government policies like liberalisation in the private seed sector to produce truthfully labelled seed and testing of the new varieties by the government and private sector encouraged seed multiplication and distribution. For instance, 82% of the seed supply of pearl millet and 75% of sorghum is by the private sector (Pray and Nagarajan 2009b). This has increased the seed replacement rate phenomenally and productivity of sorghum and pearl millet has more than doubled, benefiting farmers. The increased productivity has enabled farmers to allocate less area to millets and divert the saved land to cash crops, improving their incomes.

Comparative Economics of Sorghum and Pearl Millet Production

The profitability of rabi sorghum is relatively high compared to kharif sorghum (Table 1, p 77). Farmers cultivating kharif sorghum realise a productivity advantage due to the adoption

Figure 3: Trends in Annual Per Capita Consumption (PCC) of Sorghum and Pearl Millet in Rural and Urban India (1972 to 2010)



of hybrids like CSH 9, 16, and 23. The productivity is double that of rabi sorghum, where there are no hybrids (Figure 2, p 76). Thus, the cost of production per quintal is lower, while farmers who produce rabi sorghum have a price advantage, as its price is higher. In the case of pearl millet, the production cost per unit of output is low due to high productivity because of the large-scale adoption of hybrids, and the net margin realised per unit is modest.

Table 1: Comparative Cost of Cultivation of Kharif and Rabi Sorghum (Maharashtra) and Pearl Millet (Rajasthan)

Particulars	2009-10			2008-09			2007-08		
	KSG	RSG	PM	KSG	RSG	PM	KSG	RSG	PM
Total cost (Cost A) (Rs/ha)	14,820	11,391	7,888	12,759	10,624	7,099	14,124	8,831	5,680
Total return (Rs/ha)	19,856	16,646	14,506	17,514	16,104	13,055	18,863	15,851	10,455
Net return (over cost A)	5,036	5,255	6,618	4,755	5,479	5,956	4,739	7,021	4,775
Returns to cost ratio (over cost A)	1.34	1.46	1.84	1.37	1.52	1.83	1.34	1.80	1.84
Productivity (qt/ha)	16.57	9.38	17.32	14.93	9.92	16.00	15.54	8.37	15.00
Cost of production per quintal	895	1,214	456	855	1,071	444	909	1,055	379
Gross return per quintal	1,199	1,774	838	1,173	1,623	816	1,214	1,893	697
Net return per quintal	304	560	382	318	552	372	305	838	318

KSG = kharif sorghum grain, RSG = rabi sorghum grain, PM = pearl millet; Cost A refers to all paid-out costs, which approximates the expenditure incurred by a cultivator in cash and kind on the cultivation of the crop.
Source: Comprehensive Cost of Cultivation Scheme, Government of India.

Considering the current minimum support price (MSP) of Rs 1,175 per 100 kilograms of pearl millet and Rs 1,500 per 100 kg of rabi sorghum, farmers are not able to get higher returns. While an MSP is announced for dryland cereals, none of them, including pearl millet grains, are procured. Hence the MSP should be followed by procurement to provide market support to farmers. Unless the price scenario changes, pearl millet and sorghum will not emerge as commercial crops, and the area under these crops is likely to decline though productivity may improve with the availability of improved technology. The decline in area can be addressed through appropriate policies promoting these crops, both at the farm level and at the consumption level.

The bulk of the rabi sorghum output goes for human consumption. As a result, it commands a premium price, 20% to 40% more than kharif sorghum. Rabi sorghum fodder is also highly preferred as livestock feed, which is a key complementary activity in dryland agriculture, contributing to total farm income. The economic contribution of fodder to the total income from rabi sorghum is 45% to 57% in varieties and 39% to 47% in hybrids in Maharashtra and Andhra Pradesh (DSR 2010).

Consumption Trends

The annual per capita consumption of sorghum at the all-India level declined sharply by 74% (8.5 kg to 2 kg) in urban areas and by 81% (19.2 kg to 3.5 kg) in rural areas between 1972-73 and 2009-10. Similarly, pearl millet consumption has fallen very steeply from 11.5 kg to 3.06 kg (by 73%) in rural areas and from 4 kg to 1.08 kg (by 73%) in urban areas (Figure 3) (Parthasarathy Rao et al 2009; Basavaraj et al 2010). This is due to an increase in per capita income, growing urbanisation, and changing tastes and preferences (Chand 2007), which have made sorghum and millet inferior goods with low to negative income elasticity of demand and positive price elasticity. Apart from a decline in consumption, these crops are gradually disappearing in traditional areas due to the access to irrigation and markets, which have enabled farmers to shift to the cultivation of high-value crops (Chandrakanth and Akarsha 2011).

The food security strategy of the central government of supplying subsidised rice and wheat through the PDS has been a major factor in the decline of consumption of sorghum and other cereals such as pearl millet and finger millet in rural areas and urban centres. The popularity of sorghum and pearl millet has faded, resulting in negative growth in area, production, and consumption, as they cannot compete with other remunerative crops due to market imperfections and market failure (to recognise their nutritive properties), poor policy support, and poor consumer awareness. In addition, the improved access to irrigation has seen area under millets being gradually replaced by rice, maize, and other high-value crops. Due to low market price, farmers do not follow improved production practices and their cultivation has become uneconomical.

The PDS system in India is based on a wheat and rice model, which is less relevant in many areas, especially dryland farming areas where millets, sorghum, and pulses are traditionally the staple grains for household consumption (Dayakar Rao et al 2007). Despite the decline in per capita consumption, sorghum grain is an important staple of low- and middle-income consumers in regions where it is grown. For example, in rural areas of central Maharashtra, per capita annual consumption of sorghum is around 60 kg, accounting for almost half (48%) the per capita consumption of all cereals. Similarly, in the

major pearl millet-producing regions, per capita consumption is highest (69 kg/year) in rural Rajasthan and in the dry areas of Gujarat (59 kg/year). In these two regions, pearl millet accounts for more than 50% of cereal consumption, contributing about 20% to 40% of the total energy and protein intake (Parthasarathy Rao et al 2006).

Traditionally, sorghum and pearl millet were grown for home consumption and not for marketing. Hence, the market participation was quite low, as also their price response. As a result, these crops never fetched prices equivalent to their higher nutritive value. Currently, with the increasing importance of alternative uses, producers sell a portion of their produce and are more concerned about the prices received for it. The MSP mechanism has not been effective as the marketing of the produce is not in bulk, but mostly in local markets, which has resulted in unfair treatment on the price front (Deshpande and Rao 2003). The market for millets (except maize) is undergoing a change from near perfect to imperfect. This is due to a lack of consumer demand for millets, including from farmers who produce these crops. As these farmers face relatively imperfect markets compared to those of superior cereals, pulses, and oilseeds, the low prices make them economically inefficient, just covering or not even covering production costs. Market efficiency can be improved by the addition of processing facilities to handle excess produce in times of optimum production and by allowing for an expansion beyond the market for grains. By organising as a group, producers will be able to obtain market power, thereby increasing their share of increased profits in the chain.

Structural Constraints to Sorghum and Millet Production and Utilisation

Many studies have indicated a variety of constraints affecting millet and sorghum production and consumption. These are briefly explained, along with various strategies to overcome them.

Biotic and Abiotic Stress: Extensive land degradation and unfavourable climate are the major abiotic constraints limiting millets production in semi-arid tropics (SAT) in India. Further, biotic constraints are also major yield reducers. Most of the small and marginal farmers are risk averters. Uncertain monsoons followed by recurring droughts deter the use of costly inputs like chemical fertilisers, improved seeds, and management practices. Poor management of biotic and abiotic stresses has led to low productivity

High Post-harvest Losses, Limited Processing and Utilisation Opportunities: Lack of improved storage facilities and infrastructure at the farm level, and inadequate facilities to keep processed products have constrained increased production. Post-harvest processing of millets is still in its infancy, with no policy support. The price disadvantage of rainfed farmers due to lack of storage and bargaining capacity is exploited by middlemen, who garner the produce during peak arrivals at harvest time and store the grain to reap the time utility. The vertical integration capacities of small and marginal farmers are virtually non-existent or poor, which puts them at an additional disadvantage.

Limited Market Opportunities for Sorghum and Millets: Cultivation of millets is limited to the farm level and is not market-oriented as the width of the market is shallow and effective demand is falling. The most common complaint of smallholder farmers in rural areas is the lack of access to stable markets and market-led extension.

Limited Capacity Building and Institutional Support: Technologies have been generated but they do not reach the needy in time due to lack of effective extension efforts and are not often adopted due to lack of capital, infrastructure support, and poor market linkage.

Lack of Credit and Input Supply Bottlenecks: Financial institutions are shy to finance millets in semi-arid regions due to the risk of crop failure. Further, lack of access to and the availability of critical and quality inputs at the right time and place are common factors precluding the optimal allocation of resources, thus affecting production and productivity.

Lack of Selective Mechanisation and Labour Scarcity: Of late, labour scarcity is emerging as a severe constraint, particularly during the harvest and post-harvest seasons, reducing the profit margin of millet production. The lack of low-cost harvesters, which reduce the drudgery, is another problem.

Low Profitability: Due to the lack of economic incentives, millets have been treated as subsistence crops. A majority of the farmers in dry areas cultivate millets as fodder for their own livestock, which is a complementary activity that provides stable income. Further, the relative profitability of competing crops in terms of cost to return ratio indicates that cluster bean (1:4.5), sesamum (1:3.3), green gram (1:2.9), castor (1:2.74), and Bt cotton (1:2.5) are more profitable than millet in the western states of India. Similarly, onion (1:2.25), safflower (1:1.53) and gram (1:1.52) are more profitable than post-rainy season sorghum in Maharashtra. Thus, millet and sorghum are less remunerative compared to competing crops as they are not considered to be commercial crops (Nagaraj et al 2012).

PDS Has Contributed to the Decline in Consumption of Dryland Cereals: Rice and wheat have been distributed through the PDS at subsidised prices to people who are below the poverty line. This has severely affected the consumption pattern of cereals, as the price of dryland cereals is much higher than the subsidised prices of rice and wheat. Thus, a change in the consumption pattern has affected the growth of coarse cereals.

Options/Strategies to Overcome Constraints

A multi-pronged research strategy related to productivity enhancement through the management of biotic and abiotic stress, targeting soil and water use efficiency, reducing

drought risk, the release of varieties to cater for the demand from the processing sector, and promotion and policy action to raise profitability are some of the measures crucial to overcoming constraints. Further, alternative uses of millets need to be explored and promoted to stimulate demand for millet-based products. Value addition and developing value added products to meet the demand of the growing urban population, post-harvest processing, creating an awareness of the nutritive value and health benefits of consuming millets, capacity building of farmers, consumers, and processors, and market linkages can alleviate problems on both the production and consumption sides. The paradox of producers unable to find markets while consumers are unable to access millets in spite of their necessity has to be resolved. Providing backward and forward linkages for a value chain in nutria-millets using standardised post-harvest technologies through domestic and international markets is desirable.

Since sorghum and pearl millet occupy a prime place in the food basket in Maharashtra, Karnataka, Andhra Pradesh, Rajasthan, Gujarat, and Haryana, efforts should be made at the policymaking level to include them in the PDS in these states. This will, in the long run, help both producers and consumers. It will provide incentives to grow sorghum to producers and to consume it to consumers if it is made available at a cheaper price. Policymakers should facilitate forward linkages where farmers enter directly into agreements with industrial users through contract farming, bulk marketing, and so on. This will enable an assured price to growers while the industries can expect bulk supplies of grain of the required quality. To make a case for millets and raise consumer demand, a link has to be established between health and the consumption of traditional foodgrains. This needs initiatives from different stakeholders.

Some of the sincere efforts made by civil society development initiatives such as the Deccan Development Society, Hyderabad, and the Millet Network of India (MINI) in promoting millets need to be recognised. According to the Deccan Development Society, every hectare of millet supports 100 person days of livelihood. More than 100 million people in India live on millet-based livelihoods. In maintaining ecological security, millets play a crucial and vital role. When grown in traditional biodiverse ecologies, millet fields turn into ecological fields. A massive educational programme is required to help millets get rid of the stigma of being "inferior crops" grown by the "poor" and enable them to be known for their true worth as nutria-cereal superior crops.

The Millet Network is an all-India alliance of 65 institutions and individuals, comprising different stakeholders in the country. It has been involved in recognising and retrieving millets production and value chain activities. It advocates several measures, inter alia, inclusion of millets in the PDS to make it a food and nutritional security programme. The government should introduce millet-based foods in the Integrated Child Development Services (ICDS), school meals, and welfare programmes. These actions will open up new markets for millet farmers and revitalise them. There are a number of institutional mechanisms that need to be created, nurtured, and developed. Millets need a number of enabling conditions, and these include enhancing the productivity of the rainfed lands where millets are grown. This could be achieved through special watersheds on millet lands and dovetailing government employment programmes such as the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) to support millet cultivation from sowing to harvesting

Millets are being cultivated in harsh agro-climatic conditions without irrigation and they are low-input intensive crops compared to other commercial crops. This production system must be honoured through offering a socio-ecological bonus to millet-growing farmers (see http://www.swaraj.org/ shikshantar/ millets.pdf). The future source of output growth of millets is a function of genetically improved varieties, better management practices such as seed treatment, drilling of fertilisers along with seeds, wide row-spacing, opening of furrows, and access to different markets due to value addition as well as policy support. This needs to be separately carved out for coarse cereals to counter the slackness in their procurement and distribution.

Potential Areas for Future Investment

The potential areas for future investment are, inter alia, crop improvement, soil and moisture conservation technologies, small-scale mechanisation, food-processing technologies for better value addition, markets, institutions, policy support, and infrastructure.

In marginal and harsh environments, the option to shift from millets to other lucrative crops is limited. Hence, farmers demand productivity augmenting technologies that are cost effective and land saving. The productivity of kharif sorghum is twice that of rabi sorghum, since enhanced productivity is not substantial in rabi sorghum due to lack of varieties/hybrids that have a grain quality on a par with the local varieties, Maldandi and M35-1, which consumers prefer for grain and fodder. In addition, new sources of demand for sorghum and pearl millet are also emerging. Hence, investments should flow towards breeding varieties incorporating the quality attributes preferred by end users. It goes without saying that breeding efforts for value added characteristics, such as tolerance to drought, downy mildew, smut, blast, heat, and bird loss, should continue as the yield loss due to these is to the tune of 30% to 50%.

In the case of pearl millet, hybrid options should be expanded to marginal environments where very limited options exist now. There is a need to breed specifically for arid production systems to increase the genetic base of breeding material adapted to such regions. Pearl millet as a crop with high biomass potential should be promoted for forage to meet the fodder requirement of livestock. There is also a need to increase heat tolerance levels to ensure high grain production in the summer season crop.

In semi-arid and arid climates, natural resource management based on a watershed approach is very important for successful cropping. Hence, an investment on conservation of natural resources is a prime area. The second priority is in the area of processing technologies to increase the shelf life of pearl millet flour, reduce undesirable attributes like fat content and phenol compounds, and explore the health benefits and nutraceutical values of millet. Industrial demand for grain-based alcohol is also expected to propel a double-digit growth rate. Thus private-public partnership and investment is required in the area of processing. For instance, there will be a good demand for pearl millet for extraction of alcohol, provided the starch content is increased from the present level of 55% to 65%. Most distilleries now use broken rice as rice has high starch content and the unit cost of starch from rice is cheaper than from pearl millet. Hence, the demand for pearl millet from distilleries will depend on the relative prices of broken rice and pearl millet. To harness this potential, suitable varieties with high starch content need to be developed.

Exploring non-conventional uses and extrusion products is another important area for future investment. Incentives should be provided to the food industry to use rabi sorghum for new processed food products (snacks, bread, biscuits, flakes, papad, rava, and so on) and also traditional processed products. Value addition in millets is crucial to widen markets, for consumer acceptance, and to render cultivation of these crops remunerative for producers. Though the potential exists for bakery products, nutrifoods, nutraceuticals and health foods, value addition in millets is in its infancy, with no research and policy support. Enriching the nutritional value of pearl millet, like zinc and iron content, is yet another fertile area for investment. Millet flour is a main diet ingredient for essential minerals like iron and zinc in marginal ecologies. Hence there is wide scope to invest in nutrition technologies, which will have a ripple effect on the livelihoods of dryland farmers in marginal areas who are dependent on cultivation and consumption of crops such as sorghum and pearl millet. Further, improving the nutritional quality of fodder is an important area to improve the efficiency and productivity of livestock.

Investment on extension, infrastructure, and market linkage are crucial. Technologies have been generated but these are not reaching the needy due to lack of effective extension efforts and are often not adopted due to lack of capital, infrastructure support, and poor market linkage. Developing appropriate small-scale machinery that eases labour scarcity and reduces drudgery for women in harvesting and threshing of grain is another important grey area for private and public investment.

Research and Policy Imperatives

Research efforts targeted at improving rabi sorghum have not been accorded much importance. Even now, for rabi sorghum, the bulk of the area is occupied by Maldandi, a local landrace, and M35-1. The average replacement of seed during the cultivation of post-rainy sorghum is 16 years. Further, biological and environmental factors constrain yield improvement in the rabi season. Thus, research in the case of rabi sorghum should address enhancing productivity of grain and fodder yield in a residual moisture situation.

In pearl millet, hybrids and improved agronomic practices are lacking for marginal harsh environments like the arid zone in Rajasthan where it is predominantly grown. The research focus should be on development and popularisation of short-duration and heat and drought tolerant varieties/hybrids to meet the food and fodder security of the poor.

Any significant increase in productivity requires the use of crop improvement and management technologies, and market support as an economic incentive. In addition, biotic and abiotic stresses such as resistance to shoot fly, aphid, charcoal rot, drought, and cold are important for adaptation in the rabi season. Consumer acceptability is towards bold, round, and lustrous grain and high flour recovery. Thus, research efforts on rabi sorghum should address the above problems on a priority basis to augment productivity and render sorghum a profitable crop. Chronic undernourishment, especially deficiency of micronutrients, or hidden hunger, is rampant in India. Millets need to be included in diets to address micronutrient deficiency. The government must include millets in the PDS as a quid pro quo measure in the National Food Security Mission. Millets also need to be integrated with the ICDS, MNREGA, and school mid-day meals programmes wherever these crops are predominantly grown.

Conclusions

Pearl millet and sorghum are grown in arid and semi-arid regions of India under rainfed conditions and continue to play a prominent role in the dryland economy. These crops possess unique features such as high nutritive value and high fodder value, and are drought tolerant. The productivity of these crops increased significantly during the green revolution era due to public and private investments in research and development (R&D). Though there was enhanced productivity, lack of economic incentives and effective demand meant that farmers reduced the area under millets by shifting to other crops. A lack of prominence in all aspects of research, policy support, market support, and extension support, compared to wheat and rice, has in general affected the production and market for millets. Hence, a multipronged approach is crucial if millet production and marketing is to benefit the bulk of small and marginal farmers in SAT areas. While sorghum and pearl millet can substantially contribute to the food, nutritional, and economic security of small and

marginal farmers, it is crucial to stimulate demand for them through value addition at the micro and macro levels with technological support and market-led extension. The very fact that rabi sorghum has not made inroads despite R&D enhancing productivity, is a prima facie indicator that productivity addresses only the supply side. Consumer demand is crucial, and this is possible through value addition and extension efforts incorporating the nutrition and health aspects, and also meeting the quality requirements of alternative users emerging on the scene.

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Appendix 1