Improving Crops for Arid Lands

Pearl millet and sorghum in India

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Millions of small-scale farmers in India live in harsh environments where rainfall is limited and irrigation and fertilizer are unavailable. India's arid and semiarid lands constitute more than 50 percent of the country's geographic area and are home to 60 percent of the rural population. Farmers in states such as Andhra Pradesh, Gujarat, Karnataka, and Rajasthan have long grown sorghum and pearl millet—hardy crops that can thrive in almost any soil and survive under relatively tough conditions. Production from these crops was low, however, and so were returns to farmers, until improved, higher-producing varieties were developed and distributed starting in the 1970s. Since then, a succession of more productive and disease-resistant varieties has raised farmers' yields and improved the livelihoods of about 6 million millet-growing households and 3 million sorghum-growing households.

The success and sustainability of these improved varieties resulted from three interventions by the Indian government and the international community: increased investments in crop improvements during the 1970s, the development of efficient seed systems with a gradual inclusion of the private sector in the 1980s, and the liberalization of the Indian seed industry in the late-1990s. Thanks to these interventions, improved varieties have delivered benefits to some of the poorest people and areas in India.

An evolving partnership between public research and private industry has played a central role in getting these improved varieties out to millions of poor and small-scale farmers in India's arid and semiarid lands. By allowing farmers to grow the same amount of millet or sorghum using half as much land, these improved varieties have made it possible for farmers to shift farmland to valuable cash crops—that is, crops they can sell in the market—and thereby raise their incomes.

Dryland Farming in India

Millions of Indian farmers must eke out a living by cultivating crops in areas where rainfall is low and unreliable. Among the crops suited to these harsh conditions are millet and sorghum, which belong to a group of annual grasses that produce small grain seeds and are often cultivated as cereals. Millet comes in many varieties, including pearl millet, finger millet, little millet, and foxtail millet, but here "millet" refers to pearl millet only. Millet and sorghum are widely grown in Africa, Asia, and Russia and can be used as grain or forage. They are resistant to drought, grow quickly (the period from planting to harvest is typically three to four months), and can be cultivated in a wide range of soil types.

In India, sorghum is predominantly grown in arid and semiarid regions, particularly in the states of Andhra Pradesh, Karnataka, Maharashtra, and Tamil Nadu. Farmers can grow it with as little as 400–500 millimeters of rain a year. If rainfall is slightly higher—500–600 millimeters a year—farmers tend to prefer pearl millet over sorghum and grow it extensively in the dry western and northern regions of the country, specifically in the states of Gujarat, Haryana, and Rajasthan.

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Sorghum and millet are the principal sources of energy, protein, vitamins, and minerals for millions of the poorest people in harsh and unfavorable agricultural environments. These crops currently constitute an estimated 11.4 percent of the global cereal area harvested and 4.1 percent of the total output of world cereals.[1]

The Indian Government Invests in Millet and Sorghum Research

The first advances in millet and sorghum research in India resulted from the efforts of a range of government institutions. In the early 1960s, the Indian Council of Agricultural Research (ICAR), with assistance from the Rockefeller Foundation, initiated research on hybrid sorghum and pearl millet. Success came relatively quickly. The first sorghum hybrid (CSH-1), bred in India, was officially released for commercial cultivation in 1964, followed by the first pearl millet hybrid (HB 1) in 1965.

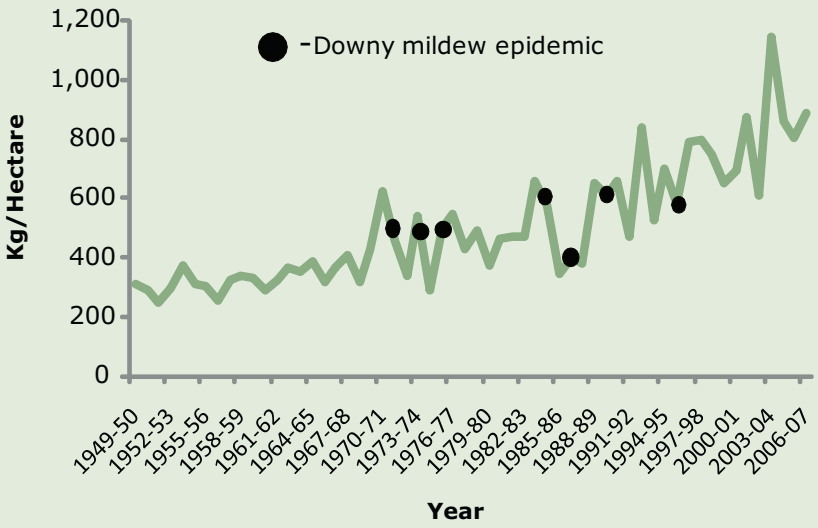
In 1967, to help organize and focus research on these two crops, ICAR initiated the All India Coordinated Millet Improvement Project, and two years later, the All India Coordinated Sorghum Improvement Project. These programs organized government research and in many locations tested for improved characteristics of hybrids and varieties—through state agricultural universities, research institutes, and experiment stations.

Pearl Millet and Downy Mildew

Plant researchers must continually issue new varieties of pearl millet to stay ahead of the threat of downy mildew. During the past few decades, a boom-and-bust pattern has developed: an improved variety of pearl millet is released to the public, generating hefty gains in productivity; a few years later, the variety becomes susceptible to downy mildew, yields fall, and the cycle begins again (see Figure 12.1).

So far, the only solution appears to be constant research to improve pearl millet's resistance to the disease. In recent years, both public and private entities have released pearl millet varieties that are resistant to downy mildew and have achieved widespread adoption, but it may only be a matter of time before these varieties, like the ones released before them, become vulnerable to the fungus and must be replaced.

Figure 12.1—Pearl millet yields and downy mildew, 1949-50 to 2006–07



Source: McGaw, E. M. 2001. *Fine tuning the progeny: Making good things even better.* Policy Brief. London: Department for International Development.

The creation of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in 1972 further stimulated research on sorghum and pearl millet and contributed substantially to the research effort on these crops.

Joint efforts by these institutions resulted in the release of a succession of pearl millet hybrids offering yield advantages. Since the mid-1960s, average grain yields have nearly doubled, even though much of the production of millet has shifted to more marginal production environments. Production of pearl millet in India currently stands at 9 million tons and hybrids cover more than half of the total national pearl millet area of 10 million hectares.[2] Researchers face a constant challenge from downy mildew, however—a fungus that can cause crop losses of up to nearly 100 percent (see box previous page).[3]

Similarly, tremendous advances in sorghum improvement resulted from decades of a partnership between ICRISAT and the Indian national agricultural research system. Although the first set of sorghum hybrids was released in the mid-1960s, many other popular hybrids have followed, augmenting the spread of sorghum hybrids and pushing up productivity, especially for *kharif* sorghum, or rainy season sorghum. The hybrids reflect impressive advances in diversifying parental lines and incorporating resistance to major pests and diseases.

Cultivating a Seed Industry

At the beginning of the Green Revolution, it became clear to the Indian government and to key state governments that state extension services and emerging private seed companies could not distribute enough seed to allow for the large-scale adoption of new varieties. The government decided to create state seed corporations, the first of which evolved out of the G. B. Pant University of Agriculture and Technology in Pantnagar. This corporation then became a model for the National Seed Corporation and other state seed corporations. The Indian government, with the financial support of the World Bank and technical assistance from the Rockefeller Foundation, financed the development of state seed corporations in most major Indian states in the 1960s. Gradually these state seed corporations replaced state departments of seed production and formed the nascent foundations of a formal seed industry.

Often, formal seed industries are taken for granted, especially in industrial countries, where agriculture is extremely productive. But in India, as in many other countries, seed industries are still emerging. The problem stems from the limited profitability of seeds. When farmers are able to plant and save seeds from one season to the next without losing much in terms of yield and output, there is little need for them to purchase new seeds—and little opportunity for seed producers to sell new seeds.

It is only when commercial seeds offer clear advantages in terms of quality and performance that farmers become more willing to purchase them. When improvements are bred into a crop, for example, farmers must buy or otherwise gain access to the improved seed to realize the benefits of breeding. Farmers must also buy seeds for hybrids, the yields of which tend to drop when grain from harvests is saved and planted in the next season (see Chapter 4).

But seed industries do not emerge simply by themselves. The right rules and regulations must be in place to encourage private investment in the industry and to limit the role of the public sector where it is a less-efficient purveyor of seed to farmers. In India, this institutional framework for the development of a seed industry emerged with the Indian Seed Act in 1966. The nascent Indian seed industry was heavily regulated under the act, however, with limited entry and formation of large firms—domestic or foreign. Private seed imports for both commercial and research purposes were restricted or banned, ostensibly to protect smallholders from predatory corporate practices.

A Private Seed Industry Emerges

Since the 1970s, the private sector has played an ever-increasing role in developing improved varieties of millet and sorghum and distributing them to farmers, through innovative partnerships with public-sector agencies. In 1971, India began deregulating the seed sector, relaxing restrictions on seed imports and private firms' entry into the seed market. This change, combined with a new seed policy in 1988, spurred enormous growth in private-sector seed supplies in India. Currently, the Indian market for agricultural seed is one of the biggest in the world.

Millet and sorghum sold at market, India

Sorghum and pearl millet breeding by private companies began around 1970, when four companies had their own sorghum and pearl millet breeding programs. By 1985 this number had grown to 10 companies. In 1981, a private company developed and released the first hybrid pearl millet.

One major reason for the spurt in private-sector growth was the strong public-sector research on sorghum and millet. International agricultural research centers such as ICRISAT exchanged breeding material with public and private research institutions. National agricultural research centers such as ICAR and agricultural universities provided breeder seed not only to the national and state seed corporations, but also to private seed companies to be multiplied and distributed through their company outlets, farmer cooperatives, and private dealers. For private firms, public institutions like ICRISAT, ICAR, and state universities provided invaluable genetic materials free of charge.

Today, more than 60 private seed companies supply improved pearl millet to small-scale farmers and account for 82 percent of the total seed supply, while more than 40 companies supply improved sorghum, accounting for 75 percent of supply. Many of these companies benefit not only from the availability of public research on improved pearl millet and sorghum, but also from innovative partnerships that specifically aim to disseminate new materials to the private sector. The most recognized of these partnerships is ICRISAT's hybrid consortia, developed in 2000–01. Private companies pay a membership fee to ICRISAT to receive nonexclusive access to hybrid parent lines that can then be used for the development and marketing of their own seed products. Although no single company has a monopoly over an individual line—all companies can use them for their own purposes as they choose—the market is currently large enough to allow all companies to compete for the smallholders' business.

The ultimate beneficiaries of this public–private system are the millions of small-scale farmers who grow sorghum and millet. Public research agencies contribute genetic materials and scientific expertise to improve crop varieties when the incentives for private-sector involvement are limited. Then, private companies take on the final development of new varieties and seed distribution—tasks to which they are often better suited than are public agencies. In this way, the benefits of crop improvements are delivered directly to farmers, who find them worthwhile enough to support financially.

Impacts of Improved Millet and Sorghum

During the past four decades, farmers have benefited from rising millet and sorghum yields (see Figure 12.2). Although yields of pearl millet stagnated for a time, perhaps owing to frequent outbreaks of downy mildew, they rebounded again in the mid-1980s, when ICRISAT released varieties with greater resistance to the fungus.

Farmers have readily adopted the improved varieties of sorghum and millet. By 1992–94, about 55 percent of the hectares of land under sorghum and pearl millet cultivation in India were planted with improved varieties, nearly doubling the productivity of both crops compared with the unimproved varieties. The area under cultivation with improved varieties continues to rise and so does productivity. In addition, as the number of varieties to choose from increases, farmers seek out more appropriate varieties for their growing conditions and consequently tend to experience more stable yields. Six million hectares of land under pearl millet cultivation (more than 60 percent of the total pearl millet area) in India are now planted with more than 70 hybrids, of which at least 80 percent are from the private sector, many based on genetic materials from ICRISAT.[4]

Because sorghum and millet are central to poor people's diets in arid and semiarid regions of India,

when yields rise, the benefits to those people are direct and immediate. In rural areas of the state of Maharashtra, sorghum accounts for 48 percent of total per capita cereal consumption, and in rural Rajasthan and dry areas of Gujarat, pearl millet accounts for more than 50 percent of cereal consumption, contributing to about 20–40 percent of people's total energy and protein intake.[5]

Besides providing more pearl millet and sorghum to consume, the improved varieties also offer significant economic returns to farmers. It has been conservatively estimated that the annual returns to India's farmers from pearl millet varieties developed by ICRISAT total US$50 million—more than 12 times the cost of its investment in pearl millet research.[6]

Sustainability of the Interventions

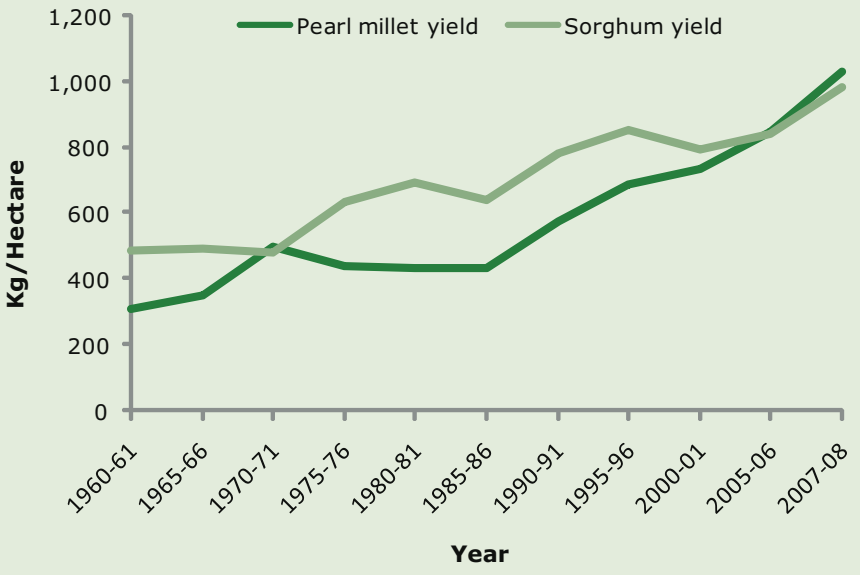
Sorghum and pearl millet policies and the programs that support them appear to be sustainable for several reasons. Farmers' demand for a range of millet crops and millet varieties in the arid and semiarid regions of India (including the states of Karnataka, Andhra Pradesh, Rajasthan, and Gujarat) is unlikely to diminish in the near future because currently few substitute crops for these harsh growing environments exist. Moreover, new sources of demand are emerging for sorghum, such as for biofuels and animal and poultry feeds.

Moreover, the public and private seed industry continues to receive valuable genetic materials from the public-sector research system and thus finds the development of new pearl millet and sorghum products profitable. Although 80–90 percent of the benefits from the adoption of sorghum and millet hybrids went to farmers, the spread of privately released hybrids shows that private firms are also benefiting enough to induce them to invest in the research and development of cultivars for small farmers in unirrigated regions.[7]

It is noteworthy that the amount of land cultivated with sorghum and millet has steadily declined. Still, overall production of pearl millet is increasing, primarily because of higher yields. These higher and more stable yields for pearl millet have enabled farmers to plant millet on a smaller area of land and to use a larger area for other crops, particularly cash crops. Sorghum yields have risen more slowly than those for millet, and thus overall sorghum production has declined along with the area under cultivation. During the rainy season, the area of land under sorghum cultivation in particular has declined considerably, owing to competition from other high-value crops such as maize, cotton, and soybean.

In India's more-favored growing environments, where farmers have access to irrigation and rising incomes are changing food-consumption patterns, the area sown to sorghum and other millet crops is gradually giving way to rice, wheat, maize, and other specialty crops. This trend is in part due to government pricing and promotion policies that favor wheat, rice, and

Figure 12.2—Yields of pearl millet and sorghum, three-year averages, 1960–61 to 2007–08



Source: India, Ministry of Agriculture. Indiastat. www.indiastat.com.
Note: For 2007–08, actual data, rather than three-year averages, were used to denote the current trend.

maize. If at some point the government decides that it cannot afford to continue subsidizing wheat, rice, and maize production, demand for sorghum and pearl millet is likely to increase.

Learning from India's Experience

All three elements of the Indian interventions to improve sorghum and pearl millet hybrids were important. First, the investments in public-sector plant-breeding and crop-management research were made by the national government, state governments, and international agricultural research centers. When hybrids of sorghum and millet were first being developed, all three of these groups contributed genetic material that benefited farmers directly and provided the basis for private researchers to develop new varieties.

Second, the government invested in seed production in public and private institutions. The Indian government and state governments, with the help of donors, made major investments in government seed corporations that multiplied the seeds of not only wheat, rice, and maize, but also pearl millet and sorghum. Seed laws were written and enforced to allow small private-sector seed companies to enter into the seed business and make profits. The government also provided training for people involved in the seed industry in both public and private institutions.

Third, India liberalized the seed sector starting in the mid-1980s. Instead of allowing state seed corporations to become regional monopolies, the government opened the doors to investment by large Indian firms and allowed foreign direct investment in the sector. This change, coupled with continuing investments in public plant breeding and public–private partnerships, has continued to provide private firms with a steady stream of genetic materials for developing proprietary hybrids. India also benefits from a seed law that allows companies to sell truthfully labeled seed without having to go through costly and time-consuming certification and registration processes for new hybrids and varieties. The result is a vibrant and sustainable supply of seed of new cultivars that are drought-tolerant and resistant to many pests and diseases.

Conclusion

Since the mid-1960s, yields of pearl millet and sorghum in India have doubled. In contrast to the major Green Revolution crops, very few yield increases of millet and sorghum is attributable to irrigation, given that 90 percent or more of these crops is grown in unirrigated, rainfed conditions. This doubling of yields has allowed farmers to grow the same amount of food using half as much land, further allowing them in many cases to shift land to valuable cash crops and increase their incomes. In addition, millet and sorghum contributed to food security because they are considerably more resistant to drought, pests, and diseases than other major food grains. Furthermore, because the wealthy tend to eat rice and wheat, the benefits of these new technologies have gone primarily to poor Indian consumers. ■

NOTES

1. FAO (Food and Agriculture Organization of the United Nations). 2009. FAOSTAT statistical database. Rome.
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