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Local Seed Systems for Millet Crops in Marginal Environments of India: Industry and Policy Perspectives

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ABSTRACT

Changes in India's seed regulations during the 1990s favored the growth of privately- as compared to publicly-funded sectors. Most advances have been made in the major millet crops, sorghum and pearl millet, as compared to finger millet and other minor millet crops, which in many ways dependent on local markets for seed purposes. In this study, we have analyzed the evolving interactions between formal systems related to the delivery of modern varieties and informal systems for maintaining traditional seeds in the semi-arid regions of India. It is evident that in these marginal environments, crop and variety use decisions, and the crop biodiversity levels take place within the context of local seed markets and a national seed industry. The outcome of the study would help to identify potential entry points for millet crop improvement and related seed system interventions for marginal environments of India.

Keywords: millet diversity, seed systems, local markets, drylands, formal seed sector, seed supply, seed industry.

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Local Seed Systems for Millet Crops in Marginal Environments of India: Industry and Policy Perspectives

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1. INTRODUCTION

Over the past two decades in India, measurable progress has been made in developing higher-yielding varieties of two major dryland crops, sorghum and pearl millet. Average national yields for these crops have more than doubled over the last four decades. The collective efforts of national and international agricultural research institutions, as well as private seed firms, have resulted in the widespread use of high-yielding millet varieties among farmers in the arid and semi-arid regions of India. Currently, 80 percent of the sorghum and pearl millet area in India is sown to high yielding varieties (HYVs), with privately bred varieties occupying a larger proportion for pearl millet compared to sorghum. Pray and Ramaswami (2001) have provided evidence that between 1987 and 1995, liberalization increased the competitiveness of the millet seed sector as well as the amount of seed research conducted by Indian and foreign seed firms. Rabobank's (2001) study of the Indian seed sector elaborated on this theme and references more recent developments.

Compared to other major food crops such as rice and wheat, however, crop improvement impacts have been less pronounced for millet growing regions of India (Evenson and Gollin 2003). There is marked seasonal and spatial variation in millet yields, and use of local varieties persists in the semi-arid areas. Findings from field research on millet systems (Nagarajan and Smale 2005; Nagarajan, Smale, and Glewwe 2005) confirmed that farming communities in the semi-arid regions of India make their economic decisions based on market prices, the policy

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environment, and the risks associated with droughts, all of which have significant implications for the generation, marketing and use of crop varieties.

In the previous two discussion papers, we demonstrated that farmers' decisions to maintain millet diversity at the household level and diversity patterns at the community level are significantly influenced by the characteristics of the seed system, in addition to household and farm physical factors. Seed system characteristics included the rate of seed replacement, seed-to-grain price ratios, distance to seed sources and the quantity of seed traded by formal and informal means. The richness of materials grown at the household and community levels is in general positively affected by the quantities of seed sold by dealers and in local shandies (weekly open-air markets), as well as the rate of seed replacement. Distances to different seed sources also influence the diversity of millet crops and varieties in these communities. Thus it is evident that in these marginal environments, crop and variety use decisions, and the crop biodiversity levels that result, take place within the context of local seed markets and a national seed industry.

Existing literature on millet seed systems (Pray and Ramaswami 2001; Pray et al 2001; Bantilan and Deb 2002; Evenson et al. 2003) has focused mainly on the two major millet crops, sorghum and pearl millet. Analysis has typically been restricted to describing the role of the formal seed sector in millet crop improvement and use of improved seed, although there are several exceptions. Tripp and Pal (1998) examined the performance of pearl millet seed market in a part of Rajasthan where farmer use of commercial varieties was expanding. Christinck (2002) described farmer seed selection and improvement strategies for pearl millet in Rajasthan, including the role of seed sharing, borrowing and exchange. Vom Brocke et al. (2003) analyzed farmer knowledge, seed management practices, and the effects of practices on the genetic structure of crop population in eastern part of Rajasthan, highlighting the importance of

understanding existing local seed systems. Each of these studies addressed either formal or informal channels, but not both, and each was confined to pearl millet.

The research that led to this paper contributes to the existing literature on millet seed systems in two ways. First, both formal and informal seed sector components are considered. Second, minor as well as major millet crops are taken into account, including seasonal variations. The purpose of the research is to help identify potential entry points for millet crop improvement and related seed system interventions for marginal environments of India.

The next section summarizes the research design for this component of the research. Section 3 includes a brief description of millet variety development and releases over the last five decades, data on market shares and margins, and adoption trends. Section 4 points out some of the challenges facing the millet seed sector in India, mentioning ongoing innovations and interventions, with reference to the national Farmers' Rights and Plant Variety Protection Act. Conclusions are drawn and implications discussed in the final section.

2. METHODS

SELECTION OF STUDY REGIONS

The states of Andhra Pradesh and Karnataka were the focus of the research presented in this paper for a number of reasons. Both states are located in semi-arid production environments, where farmers plant extensive areas to several millet crops and combinations of improved varieties, hybrids, and local varieties. Moreover, there was prior evidence that considerable genetic diversity is found among local millet varieties in these areas (ICAR 2002). With only 25 percent of all crop area under irrigation, Andhra Pradesh and Karnataka are considered major

secondary centers of origin for sorghum and other minor millets[4]. Hyderabad, the capital city of Andhra Pradesh, is also the headquarters for a number of seed companies. Known as the seed capital of India, these companies produce nearly 80 percent of the improved seeds sold nationwide for cereal crops, cotton, and sunflower.

In 2001-02, Karnataka ranked second (next to Maharastra) and Andhra Pradesh fifth in terms of sorghum area and production in India. The crop accounts for 18 percent of the cultivated cereal production in Karnataka and 7 percent in Andhra Pradesh. In terms of finger millet area and production, Karnataka is India's most important state, while Andhra Pradesh ranks third, constituting more than 60 percent of the national totals on both counts.

SEED SYSTEM SURVEY

To better understand the evolving interactions between formal institutions related to the delivery of modern varieties of seeds and informal systems for maintaining traditional seeds, survey instruments were designed to elicit information about both. The informal millet seed system comprises the exchange of information and seeds through village seed experts and traders in community seed markets or shandies; in the case of the formal millet seed system, the actors identified include grain traders in the district market yards, seed distributors, input dealers and private seed companies (Nagarajan and Smale 2005). A statistical survey was conducted at the household level, followed by key informant interviews and focus group interviews conducted with market participants.

[4] ICRISAT (1997-98) has identified 71 unique cultivars of sorghum and 14 cultivars of finger millet in Andhra Pradesh and Karnataka. In our survey sites alone, 63 unique cultivars of sorghum, pearl millet, finger millet, little and foxtail millet were identified.

SELECTION OF THE SAMPLE

In the study area, formal channels for seed transactions encompass traders in the district market yards, seed exchanges through private dealers and distributors, and seeds marketed by private companies. Millet seed exchanged through agents in formal channels is often branded, the transactions are monetized, and those engaged in the business are usually full-time traders. In contrast, traders operating in shandies are part-time. Seeds traded in shandies are not branded, since they originate from farmers from surrounding villages or communities. To some extent, the seeds are identified by their village name or, in some cases, for e.g. by the farmer's name (if the farmer is reputed in the locality for the quality of seeds). The seed exchanges are monetized but the prices are not based on 'the existing market prices', nor are they 'fixed' – they vary according to the demand and quality (physical purity) of the seeds. Seed dealers/distributors in the formal seed supply chain are a vital link between the formal seed producing firms and farming communities. Each of these actors was interviewed. A more detailed description and analysis of the actors in the informal system and local dealers can be found in Nagarajan and Smale (2005).

Here, we present only the results from the personal interviews with representatives from private seed companies and public sector institutions engaged in millet seed production and marketing. This part of the formal market chain is engaged in product development and dissemination, while participating in the promotion of seed sector policies that affecting genetic resources. In this aspect of the research, a list of private seed firms specializing in millet crops/seeds, documented by ICRISAT (2002-03), served as the basis for our sample selection. The seed firms located in and around the state capitals of Andhra Pradesh (Hyderabad) and Karnataka (Bangalore) were classified into different categories based on their size of annual seed

sales value over the past few years. The actors in the chain were sampled based on their geographical location, spread and volume of seeds they handled. A total of 45 companies (21 small; 16 medium and 8 large firms) engaged in sorghum and pearl millet were listed based on their firm size and share of millet seeds in their total crop portfolio, alphabetically. Since the total number was small, all were contacted rather than drawing a sample. Due to logistical difficulties, the information was gathered from only 22 out of 45 firms. Respondents represent the underlying distribution of firms by size category fairly well, however.

The survey questionnaire used at the firm level contained two parts. One part elicited information about the firm's share in seed production and marketing. Another was designed to elicit information about their research and other policies related to their activities. The survey was administered during January – February 2004. Table 1 summarizes the different categories of seeds firms that have been surveyed to elicit information on the nature and share of the millet seeds transacted in the past 3 years (2000-2003).

Table 1--Characteristics of seed companies surveyed, 1998-2002

Firm size	Number of firms surveyed	Average annual sales	Millet share of total sales
	(Count)	*(Million Rs)*	*(Percent)*
Small	9	980	10-12
Medium	8	1750	15-18
Large	5	2200	5
All firms	22	1645[a]	10

Source: From the firm level surveys conducted in January – February 2004.
Note: Average annual sales are calculated over 2000-2003.
[a] Average of mid-point of each firm's range.

Secondary data on millet area, production and yield, variety release and adoption, and seed production were collected from the following sources: the National Research Center for Sorghum (NRCS), ICRISAT; the Seedsmen Association of Andhra Pradesh in Hyderabad; State

Departments of Agriculture in Andhra Pradesh and Karnataka; ICAR Center for Small Millets located in University of Agricultural Sciences (UAS), Bangalore. With regard to public sector involvement in seed production and marketing, most of the information was compiled from secondary level sources of data and cross-checked with officials from the sector. Information regarding the role of public research institutions in millet research, exchange of seeds and germplasm, policy-related issues such as IP and farmers' rights, was assembled through interviewing the scientists from the research centers (ICRISAT, NRCS), state agricultural universities (Andhra Pradesh Agricultural University, University of Agricultural Sciences) and seed association members.

3. VARIETY DEVELOPMENT AND RELEASES

India's National Agricultural Research Systems (NARS) comprises public agencies, universities and private companies, some that have been seeking to develop improved varieties of millet and sorghum since the early 1960s (Pray et al.1991). Established in 1972, the International Crops Research Institute for the Semi-arid Tropics (ICRISAT) has further strengthened research on these two crops, with the active participation of public agencies in the national system. These national and international efforts have led to the development of more than 100 cultivars suitable for cultivation in India since 1975, including open-pollinating varieties and hybrids. These public research partnerships have also stimulated private efforts to research and market improved millet and sorghum varieties. Increasingly private firms are undertaking crop improvement research or they have alliances with multinationals for research support. Some of the prominent public research agencies engaged in millets research are the National Dryland Research Center (Hyderabad), the All-India Millet Improvement Research

project of ICAR (Indian Council of Agricultural Research), and the Small Millets Research Program at the University of Agricultural Sciences (UAS, Bangalore).

A range of improved materials developed by ICRISAT are widely used by many national plant breeding programs. Improved crop varieties and breeding lines developed by ICRISAT and the Indian public research institutes also constitute a major source of breeding materials for private seed companies. A survey of private seed companies conducted by ICRISAT and Rutgers University (1998) revealed that pearl millet breeding lines from ICRISAT are the base material for 80 percent of the research products i.e., newly developed varieties from private seed firms. A study on the impacts of ICRISAT's research also showed that the proprietary varieties released millet varieties relied heavily on ICRISAT-developed male-sterile and restorers in developing their hybrid pearl millet and sorghum (Bantilan and Deb 2002). Irrespective of origin of varieties, all the new varieties to be released go through the regular varietal release process and seed certification procedures. Over the years, more than 50 private companies marketing approximately 75 hybrids of pearl millet and nearly 11 companies marketing 20 hybrids of sorghum were based on seed and pollen parents from ICRISAT.

The data assembled in Table 2 suggest that in the past four decades, there has been a steady increase in the release of new, improved cultivars of pearl millet and sorghum from both public and private research institutes in India.

Table 2-- Number of millet crop varieties released in India, 1961-2001

Release period	ICAR		ICRISAT		State agricultural universities and private firms		ICAR and state agricultural universities
	Sorghum	Pearl Millet	Sorghum	Pearl Millet	Sorghum	Pearl Millet	Minor Millets[a]
1961-70	Nr	nr	nr	nr	9	5	Na
1971-80	1	3	2	nr	39	10	Na
1981-90	Nr	3	8	14	53	23	16
1991-2000	32	79	13	28	58	7	26
Total	33	85	23	42	159	45	42

Source: Agricultural Research Data Book (2002) and ICRISAT Annual Report (2002).
Note: The period of variety release refers to 1991-1998.
[a] Here, minor millets include only finger millet because no data were available for little and foxtail millet types.
'nr' refers to no release; 'na" refers to data not available.

For minor millets, the story is different. Though finger millet is an important food crop in many southern and northern states of India, it has received far less research investment than the major millets. Currently, research on minor or small millets is conducted in eleven ICAR centers, mainly coordinated through state agricultural universities in India. The states of Karnataka, Andhra Pradesh and Tamil Nadu lead crop improvement research on minor millet crops. Recognizing the importance of conservation of minor millet crop genetic resources, a germplasm unit was established in UAS, Bangalore, in 1980. At present, nearly 11,500 accessions of various minor millets, probably one of the largest base collections maintained anywhere in the world (Seetharam 1998, Seetharam and Prasad Rao 1998). Today more than 40 improved varieties of finger millet are recommended for cultivation in different states in India. Most of the released varieties are pure-line selections from existing farmers' varieties or local germplasm. Some high-yielding varieties of finger millet with insect and disease resistances were also released in late 1990s, and are mostly open-pollinated varieties. As far as the other minor crops such as little and foxtail millets are concerned, not much has been directed towards crop improvement, with the exception of some publicly funded projects in Karnataka and Tamil

Nadu. Private companies show little interest in the development of new varieties of minor millets. One reason is that most are self-pollinating and is difficult to exploit their heterosis for further hybrid development. Another is their minor commercial importance at present in terms of trade, total area planted, and research efforts aimed at crop improvement, but still considered important from the food and fodder uses especially during the post-rainy season.

Two major points emerge in reviewing the information about variety releases. First, though considerable progress has been made during 1990s, most is concentrated on the two major crops, pearl millet and sorghum. Second is the role of the international research center in underpinning private sector breeding advances.

MARKET SHARES

Until the late 1980s, public agencies played a major role in millet variety development, multiplication of seeds and their distribution through seed outlets operated by state departments of agriculture, national and state seeds corporations, and farmer cooperatives. Beginning around the early 1990s, small-sized private seed firms began bulking up publicly bred varieties and distributing the seed through their own network of private dealers. Traditionally, only licensed firms could operate domestically in India, limiting the entry and formation of large firms (domestic or foreign) and the private importation of seeds for either commercial or research purposes. The inevitable consequence of these polices was a seed supply system dominated by the public sector. However, in keeping with efforts to reform the roles of government in the Indian economy that began in the 1980s, a series of regulatory and trade reforms affecting the seed sector was initiated. These have stimulated domestic and multi-national private participation in this market. Nonetheless, the Government of India (GOI) still regulates the seed sector and trade in many ways. The various regulatory policies and laws governing the Indian

seed sector can be classified into three major groups, including 1) seed sector regulations and quality controls, 2) phytosanitary regulations and laws, and 3) polices related to the implementation of intellectual property rights. A detailed summary of changes that have taken place in the Indian seed sector has been summarized in Annex 1.

Private companies commenced breeding their own millet varieties in the 1970s, but it took a decade to produce the first commercially successful improved varieties. A recent Government of India report (2002-03) on the status of Indian agriculture claimed that nearly 80 percent of the commercial seed sales of pearl millet and sorghum are made via private seed companies (Annex 2). Maize, sorghum, and pearl millet are the three most widely planted cereals in India after rice and wheat. In terms of millet sales and acreage in India, pearl millet (with 10 percent of the total cropped area and 35 percent of total millet seed sales by value) and sorghum (with 15 percent of the total cropped area and 30 percent of the total millet seed sales), together constituted about 12 percent of the total value of seeds sold commercially in 1999-2000. Table 3 gives an overview of the sources and types of seeds marketed in the early versus late 1990s.

Saved seed refers to the seeds retained by the farmers at the end of the season from their harvest for re-use in the subsequent season.

The changing composition of Indian cereal seed markets (Table 3) refers to a point in two time period, mostly for certified seeds. Saved seed is a dominant, although declining source of seed for all the crops listed except sorghum. The data suggest that the proportion of sorghum planted from saved seed increased during 1990s. There was an abrupt increase in the sale of proprietary hybrids for pearl millet (over nine fold increase in the 1990s) and maize (a three fold increase), as well as sorghum (from 6 to 10 percent). In contrast to proprietary hybrids marketed by private companies, sales of publicly bred sorghum and pearl millet hybrids have declined

considerably. Publicly bred hybrids continue to dominate the sorghum hybrid market, however. Especially proprietary sorghum hybrids and OPVs could not compete with the public bred sorghum products because of quality constraints and lack of wide variety of germplasm to suite local environments. Thus proprietary sorghum products lost their competitive edge to publicly-bred, sorghum OPVs and hybrids. Also, most of the sorghum areas in India are still under rainfed cultivation or in areas with limited irrigation potential; still the higher use of OPVs persists. Most of the public bred hybrids are marketed through state and national seed corporations in the respective regions. They are also given for further multiplication through license arrangements to private firms, farmer's organizations or cooperatives exclusively or with a buy back arrangement through state agricultural departments. There was also a significant reduction in the sale of open-pollinated varieties (OPVs) of pearl millet from 1990-91 to 1998-99, but an increase in sales of sorghum OPVs during the same period. During this period, the private seed firms entered the market with millet hybrids with proven yield advantages over the existing OPVs. However, the private firms' sorghum research was not as efficient as pearl millet.

During interviews, private firms suggested that publicly bred hybrids such as the CSH series of sorghum have outperformed their own offering. Sales of pearl millet hybrids increased due to its yield advantage compared with open-pollinated varieties, bolstered by the active market promotion of private companies. In the case of pearl millet the private firms could exploit the heterotic vigor fully and especially after accessing premium base materials from the national and the international centers (ICRISAT), the private firms with their research capacity started producing three-way cross hybrids very quickly; also backed up by active market promotion activities gave them an edge over public bred varieties or hybrids. Our interviews

further indicated that private companies foresee further area expansion under pearl millet in new areas, especially in Gujarat and in some parts of Maharastra.

Table 3-- The changing composition of Indian cereal seed markets

Crops	Saved seed [a]		Proprietary seed [b]		Public-bred hybrid [c]		Open-pollinated variety [d]		Total	
	1990-91	1998-99	1990-91	1998-99	1990-91	1998-99	1990-91	1998-99	1990-91	1998-99
					(Metric tons)					
Sorghum	63256	48195	6200	7400	30400	11855	2100	3425	101956	70875
Pearl millet	49806	38445	1400	11350	10100	6682	6500	3523	67806	60000
Maize	63336	55793	8000	24000	11671	11671	5729	na	88736	91464
Rice	1144408	1138654	na	537	na	na	na	200402	na	1339593
Wheat	2272000	2927075	na	Na	na	na	145000	289491	2417000	3216566
Total	3592806	4208162	15600	52171	52171	30208	297329	496841	3957906	4778498
					(Percent)					
Sorghum	62.0	68.0	6.1	10.4	29.8	16.7	2.1	4.8	100.0	100.0
Pearl millet	73.5	64.1	2.1	18.9	14.9	11.1	9.6	5.9	100.0	100.0
Maize	71.4	61.0	9.0	26.2	13.2	12.8	6.5	na	100.0	Na
Rice	na	85.0	na	0.0	na	na	na	15.0	na	Na
Wheat	94.0	91.0	na	Na	na	na	6.0	9.0	na	Na
Total	90.8	88.1	0.4	1.1	1.3	0.6	7.5	10.4	100.0	100.0

Source: Compiled by author based on marketing data base, bench marking the seed market (Mahyco 1999 and 2000-01).
Note: na refers to data 'not available'.
[a] Here saved seeds refers to the seeds retained by farmers at the end of one season for re-use in the subsequent season.
[b] Proprietary hybrids denote the cultivars released by the research efforts of private companies.
[c] Public hybrids refers to the cultivars released by the efforts of public institutions such as international, national and state agricultural universities.
[d] Variety refers to improved, high-yielding, open-pollinated cultivars released by both public institutions and private firms.

Changes in seed regulations and policies in India during the 1990s have favored the growth of private versus public seed sectors, but also differentiation by firm size. Combining evidence in Rabobank (2001) with information gained from our recent surveys of the Indian seed sector in 2003-04, we estimate that 82 percent of the commercial sales of sorghum seeds and 77 percent of the commercial sales of pearl millet seeds involve large-sized private seed companies. The rest is shared roughly equally among small- and medium-sized private companies along with the public sector. A noteworthy recent trend is the increasing market presence of multinational companies, often partnered with domestic seed companies for research and other agri-input supply such as pesticides and fertilizers (e.g., Pioneer with Dupont and Mahyco with Monsanto). Table 4 identifies the key private firms involved in producing and marketing millet seeds in India.

Table 4 Share of pearl millet and sorghum seed sales by major private firms, 2002

Company	Ownership[a] *(percent)*	Holding structure	Annual Turnover *(Rs.Million)*	Share of Indian Sales Pearl Millet *(Percent)*	Sorghum
Mahyco	74:26 D/F	Mahyco/Monsanto	1000	10	5
Pro-agro	55:45 F/D	Bayer	750	20	10
Mahendra	50:50 D/ F	Emergent genetics	600	10	20
Pioneer	100 F	Dupont	750	15	15
JK agri genetics	100 D	JK group	350	20	15
Nath seeds	100 D	Nath group	700	5	5
HLL	50:50 D/ F	Emergent genetics	125	2	2
Advanta	100 F	Zeneca	60	10	5
Others	na		NA	8	33

Source: Author survey (2003-04) and Rabobank (2001).
[a] 'D' refers to domestic ownership and 'F' refers to foreign ownership.

Among the 22 firms we surveyed in early 2004, millet and sorghum seed sales ranged from 5 to 18 percent of total firm-level seed sales depending on the size of the firm. Among the private hybrids, sorghum varieties released by Mahyco and Advanta lead the market in Andhra Pradesh. Karnataka and Maharastra, together accounting for nearly 60 percent of the sorghum produced in India, are increasingly being sown to privately developed hybrids (ICRISAT 2001).

Pearl millet and sorghum constituted a greater share of total seed sales for medium and small sized companies than for larger firms. Medium-sized firms obtained a greater share of their sorghum and pearl millet sales from open pollinated varieties compared with large firms. Large-sized firms concentrated more on high value, low volume hybrids where profit margins are higher compared with open pollinated varieties[5].

The 2003-04 survey of seed firms confirmed that almost all the large-sized seed firms engage in R&D, compared to only half of the medium-sized firms (Table 5). Almost none of the small sized firms we interviewed had R&D capacity. Mostly small firms specialized in re-production and marketing of existing popular, licensed varieties. The R&D capacity of medium-sized firms differs from that of large firms. Medium-sized firms develop semi-finished projects, with either one of the parents obtained from a public institution. They also multiply existing popular varieties released by other medium sized firms. Some specialize in exclusive development of new crop products either from their own R&D capability or utilizing the parents of public-bred or other private firms. In some cases, medium sized firms collaborate with each other in the exchange of parent materials. The large-sized firms also obtain parental materials from public sector institution for further research and development, but the R&D activities of large sized firms is dependent mainly on their own capacity. They seldom collaborate with other companies excepting through partnerships with multinational or foreign firms. They also undertake licensing arrangements for other agri-inputs such as pesticides and fertilizers (e.g. DuPont and Pioneer).

In fact, most of the firms with R&D capacity are either multinational companies or they have partnerships with foreign companies. The R&D capacity of multinational companies are a

[5] The hybrids are low-volume but high-value products, cornering maximum share in terms of their sales. (The approximate ratio of sowing between OPV and Hybrid in the case of pearl millet is approx. 2:1).

bit different from those of large and medium sized national firms; they bring their own technology which was developed abroad modified to suite the local environments. In most cases, the MNCs either bundle their activities along with other agri-inputs, for e.g. Pioneer with DuPont to complement their operations. But in order to access local materials and to avoid stiff competition from the local firms (small and medium), MNCs often partner with the existing domestic firms. Indeed, the basic research (germplasm exploration to crop improvement) carried out by ICRISAT/ICAR in the early 1970s paved way for the initiation of commercialization in sorghum and pearl millet. Currently private sector in India is ahead in terms of volume and value of millet seed sales and advanced scientific capabilities of certain technologies (e.g. CRY gene technology, apomixes).

Nevertheless the public institutes with their massive infrastructure and scientific manpower are still an attractive proposition to the private firms –for e.g. the consortia formed by ICRISAT is funded by nearly 30 private firms. In the case of medium and small sized firms, in order to appropriate the benefits of research and development, seven like-minded companies joined together to form a consortium among themselves in 2002 in Hyderabad. The consortium was formed under the leadership of Prabhat-Agro and Ganga-Kaveri Private Seed Limited with contributions from five other medium- and small-sized firms with substantial millet market shares in various regions of India. They jointly fund some of the on-going biotech and hybrid research on millet crops and cotton in order to share benefits from the research.

In summary, while the private companies dominate the sales of millet varieties in general, seed saving remains a prominent feature of the Indian market and the record depends on the crop. While hybrids have overtaken improved open-pollinated varieties in pearl millet, this is not the case for sorghum. Furthermore, some publicly bred sorghum hybrids appear to be more

popular than proprietary sorghum hybrids. The private pearl millet hybrids are nearly 25-30 percent costlier than public hybrids. In the case of sorghum hybrids, the price difference is nearly 5-10 percent. Again the price depends on the popularity of the variety/hybrid (in terms of its qualities) among the farmers and the demand.

In general, the R&D capability of large sized firms is higher than that of medium sized firms in terms of human resources, investment proportions, laboratories and field trial, and the portfolio of crops, while smaller firms have no R&D capacity. There is also a huge difference among these firms by the way they operate. Most of the large firms during our interview complained that small and medium sized firms do very little research but corner more profits by acquiring licensing and marketing rights6. In short, the large firms felt that the overhead expenditure and stake (responsibility) in seed production and marketing are much higher for them compared to small and medium firms. Small and medium firms felt that large firms have more market power and control because of their R&D capabilities and economies of scale [Table 5].

[6] Licensing fee usually incurred by the firm on procuring the parent material for further multiplication/marketing of a specific variety from another firm. This fee is negotiated based on the popularity of the parents for a particular period of time and the variety. The licensing can be given either for multiplication or marketing purposes exclusively or for both. Based on that, the fee structure would be determined.

Table 5--Varietal composition of private firm releases, 1998-2002

Firm size	Firms with own R&D	Firms with foreign ownership	Millet share of total sales	Varieties released			
				Pearl millet		Sorghum	
				OPV	Hybrids	OPV	Hybrids
				(Count)			
	(Count)		*(Percent)*	*(Count)*			
Small	0	0	10 - 12	7	14	18	10
Medium	4	2	15-18	10	25	15	21
Large	5	3	5	7	28	11	22
Average[a]	9	5	10	8	22.3	14.6	17.6

Source: From the firm level surveys conducted in January –February 2004.
[a] Average of mid-point of each firm's range.
Figures indicate the varieties released in the last 3-5 years between the two major millet crops namely pearl millet and sorghum. The sales turn over is calculated for the three year average from 2002-03 for the firms.

MARKETING MARGINS[7]

The preference for hybrid varieties among the commercial seed companies is centered on profit motives and the appropriation of higher yield gains. A detailed analysis of marketing margins was conducted based on survey findings, representing various points in the seed research, production, and marketing chain. The markup involved in procuring seed grown from farmer growers (specialists, often contracted), processing and packing it, and marketing it through wholesalers, distributors, and dealers to farmers is of particular interest. Seed producer margins were calculated for both public and private hybrids, for various varieties of millet crops, and for alternative channels (either private or public seed corporations) through which they are supplied (Table 6). As expected, seed producer margins were highest for private hybrids of pearl millet (Rs. 39 to 40 per kg), followed by public hybrids of sorghum (Rs. 26 to 29 per kg) and

[7] The seed marketing mark-ups are different from licensing fee. The firms can negotiate sometimes to provide the part of their total seed sales of that particular variety as the fee paid. But this kind of arrangement occurs only in between small or medium sized firms on a local scale to achieve their market leadership.

private hybrids of sorghum. The producer margins[8] for open-pollinated varieties of millet crops were low compared to hybrids. Only publicly bred sorghum hybrids had a higher margin than private hybrids. It should be also noted that the private firms have a higher margin by selling public hybrids than the state firms especially for sorghum.

There are many reasons why seed producer margins for publicly-bred open-pollinated and hybrid varieties are generally lower than the margins for privately bred materials. Interviews with company representatives and farmer seed producers indicated that the publicly bred varieties lack traits such as grain quality and luster that are desired by producers and consumers. The public-bred hybrids failed on two fronts especially in developing good hybrids or varieties adaptive to the local environments and in the provision of quality planting material at the right time. Publicly-bred varieties of sorghum and hybrids (e.g. *CSH series and M-35-1*) are still popular among farmers, however. The sorghum market is still dominated by open-pollinated varieties, and publicly-bred varieties with good yields and early maturing varieties are preferred by the farmers.

Analysis of price spreads[9] among different actors in the seed distribution system also shows that privately bred hybrids of pearl millet have the maximum margins for a seed producer (Rs. 70 to 87 per kg of seed sold). The minimum spreads are for improved open-pollinated varieties of finger millet, consisting primarily of publicly bred varieties. The average mark-up ranges between 10 to 12 percent of the distributor cost, exclusive of their marketing cost. Next to distributors in the marketing chain are the seed dealers, who sell all kinds of proprietary hybrids and varieties (released by private firms) and in some cases, public varieties as well.

[8] Seed producer margin = [Wholesale price] – [Producer procurement price + Processing and packing cost]
[9] Price spread = Retail Price – Producer Procurement Price.

The distributors are higher in the chain and they deal large or whole sale quantities. They can be exclusive supplier of seeds representing certain seed firms or they deal with multiple varieties from various firms. They also have a huge network of seed suppliers or dealers in the region through which they distribute seeds. Dealers form the vital link between the seed producers and users, namely farmers at the community level. The location of dealers ranges from district headquarters to local markets in small towns, thus ensuring their proximity to farmers. Dealers prefer trading proprietary hybrids because the profit margins are higher than public varieties. They also sell self-labeled or truthfully labeled seeds (TFL) procured from well-known seed farmers to cater to local demands.[10] In the case of minor millets and post-rainy season sorghum, sometimes these dealers (especially at the village level) to meet the demand of the local communities for the provision of local cultivars, the dealers procure seeds from the farmers in the neighboring communities (this involves no certification) and sell it through their shops especially during planting season. Dealers also serve as an important source of information to the farming community (Tripp and Pal 1998). Thus in a seed supply chain, dealers play a significant role in the exchange of seed materials because of their presence in local markets.

[10] In the case of truthfully labeled seeds (TFL) – improved varieties of either public or private firms can be multiplied by an authenticated individual, farmer seed producer or the farmer organizations. They can be sold as TFL seeds with the name of the released variety. Thus TFL gives only the authentic multiplication and sales right to the concerned parties.

Table 7-- Seed company margins for millets, 2001-02

	Procurement price from seed producers	Processing & packing cost	Seed marketing company mark-up[a]	Wholesale price[b]	Distributor price	Dealer Price	Retail Price	Price Spread[c]
Sorghum (Rs per Kg.)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Private companies								
Private hybrids	15-18	0.75-1.25	26.25-26.75	42-45	45-50	50-52	60-65	45-47
Private varieties	8-10	1.00	10.00	20	20-25	28-35	30-40	22-30
Public hybrids	10-12	0.75-1.25	29.25-26.75	40	45	50-52	50-55	40-43
State seed corporations								
Public hybrid	10-15	0.75-1.25	27.25-25.25	38-42	40-42	45-48	50-55	40
Public variety	8-10	1.00	5.00	15	18-20	20-25	25-30	17-20

Table 7-- Seed company margins for millets, 2001-02 (continued)

	Procurement price from seed producers	Processing & packing cost	Seed marketing company mark-up[a]	Wholesale price[b]	Distributor price	Dealer Price	Retail Price	Price Spread[c]
Pearl Millet (Rs per Kg.)								
Private companies								
Private hybrid	20-23	0.75-1.25	39.25-40.75	60-65	60-75	75-80	90-110	70-87
Private varieties	5-7	1.00	4.00	10-12	15-20	20-30	25-40	20-33
Public hybrids	15-20	0.75-1.25	13.75-14.25	30-35	45-50	50-52	65-70	50
State seed corporations								
Public hybrids	10-15	0.75-1.25	15.75-19.25	30-32	45-50	50-55	55-60	45
Public varieties	5-6	1.00	4.00-5.00	10-12	15-18	20-25	35-38	30-32
Finger Millet (Rs per Kg.)								
Public varieties	3-5	0.75	4.25	na	na	8-10	10-15	7-10

Source: Calculated from company surveys conducted during January-February 2004.

[a] Seed producer margin= [Wholesale price]- [Producer procurement price+ Processing and Procurement cost].

[b] *Wholesale prices are the average prices from the secondary sources collected during the survey. State seed corporation prices are averages of two states, Andhra Pradesh and Karnataka.*

[c] *Price spread = Retail price – Producer procurement price.*

VARIETY ADOPTION

Farmer adoption of improved pearl millet and sorghum varieties (both hybrids and open pollinated varieties) has increased dramatically from the mid 1960s (Figure 1). The rate of uptake of improved wheat and rice varieties exceeded that for sorghum and pearl millet from the mid 1960s to early 1990s, but the relative growth rates were reversed thereafter, so that the crop area shares in improved sorghum and millet varieties are now comparable to those of rice and wheat. It is also evident that the adoption of privately released hybrids of pearl millet increased during the 1990s. As noted above, most of these hybrids contain parent materials from ICRISAT and other public research agencies.[11]

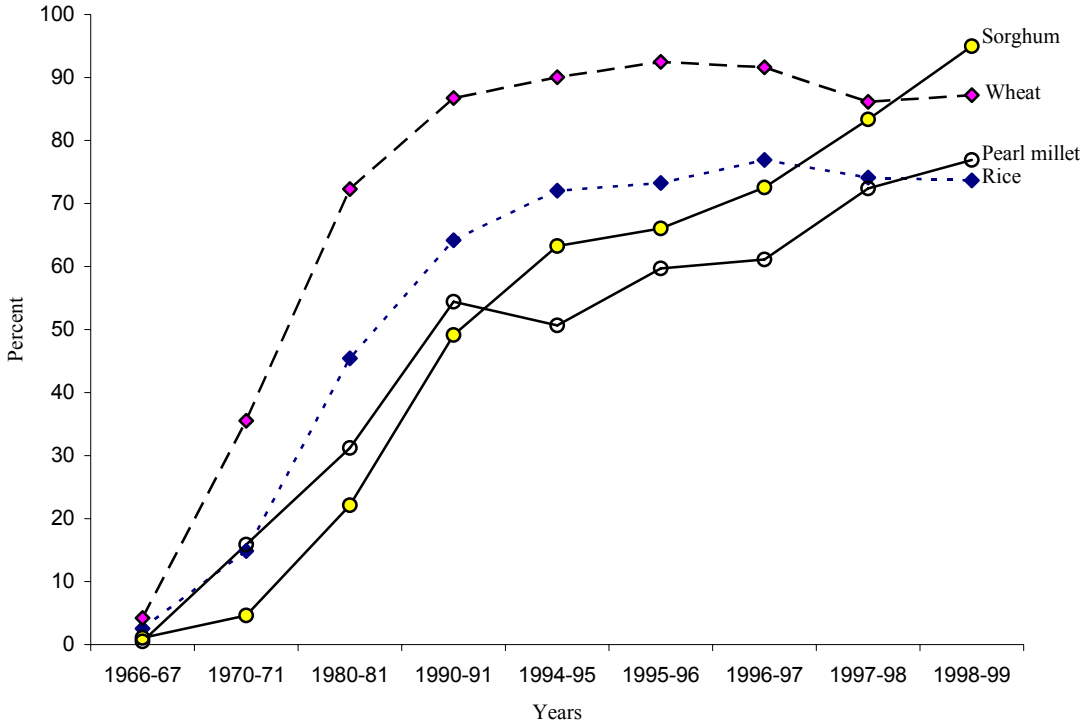
Cumulative adoption rates for major millet crops should be interpreted with caution, however. Adoption is much more pronounced in irrigated and favorable regions of the country, and a gap persists between adoption rates in these regions and the arid and semi-arid environments (Personal communication with scientists at ICRISAT, NRCS, Hyderabad 2003-04). The use of improved cultivars of pearl millets is most pronounced in the states of Maharastra, Gujarat (up to 90 percent), Haryana (85 percent) and Tamil Nadu (80 percent). Andhra Pradesh and Karnataka rank 8th and 9th in terms of adoption of improved cultivars of pearl millet in India. Local varieties still dominate in Rajasthan and in other pearl millet growing areas of India.

Pearl millet yields in Andhra Pradesh, Karnataka, and Maharastra have increased over the past ten years (Harinarayana 2001). Though these three states are not major states for the production of pearl millet, discussion with private company representatives suggests there is real

[11] Until now the parent materials procured from the public research institutes haven't received any royalty or compensation for their exchange. The proposed PPV&FR (2001) with its provisions on benefits sharing is a welcoming proposition especially from the perspective of public institutions involved in basic research.

potential in terms of increased acreage in Maharastra and Karnataka. Private companies are hoping to switch nearly 25-30 percent of the rainy season sorghum growers in Karnataka and Maharastra during the next five years over to growing pearl millet hybrids.

Figure 1--Cumulative percent of area planted to f high-yielding varieties of major crops in India, from 1960-61 to 1998-99



Source: Developed from data reported in Agri-statistics, Government of India (2003).

A similar situation is visible for sorghum, although to a lesser extent. Bantilan and Deb (2002) estimated that 71 percent of the total sorghum area in India was planted to improved varieties by 1988-89, with higher rates of use during the rainy compared to the post-rainy season. Privately bred hybrids of sorghum and pearl millet have had the greatest impact in terms of area sown and yields in the states of Andhra Pradesh, Karnataka, and Maharastra (Pray and

Ramaswami 2001). Table 7 gives an account of the spread of private hybrids and their impact on yields of pearl millet and sorghum at three different points of time (1990, 1995 and 2001) in these three states.

Table 7--Diffusion rates and yields for private hybrids in selected states

Crop and state	Area under private hybrids[b]			Yield		
	1990	1995	2000-01	1990	1995	2000-01[a]
		(Percent)			*(T/Ha)*	
Sorghum						
Andhra Pradesh	9	29	25-27	0.64	0.74	0.69
Karnataka	29	46	51	0.87	1.04	1.18
Maharastra	8	18	23	0.91	1.00	1.32
Pearl Millet						
Andhra Pradesh	10	33	34	0.68	0.80	0.90
Karnataka	10	24	27-30	0.48	0.54	0.65
Maharastra	34	42	40	0.45	0.63	0.75

Source: Pray and Ramaswami (1998) for 1990 and 1995 data and author survey for 2000-01 data.
[a] Calculated from the private company market estimates given by the concerned representatives and averaged across the different regions in the selected states.
[b] The percent area adoption are based on estimates by private seed firms and cross checked with state department of agriculture sources and ICRISAT.

In recent years, both use of sorghum hybrids and yield levels have declined in Andhra Pradesh. Survey respondents suggested that changing consumption patterns, along with the switch from sorghum to maize, cotton and soybean crops are among the more significant reasons behind this change. Our household survey data on variety use also indicates the increasing use of private hybrids for sorghum and pearl millet, whereas in the case of minor millet crops, farmers' varieties are prominent (Annex 3).

At the regional level there is decline in the use of sorghum and pearl millet which coincides with the decline in their acreage in recent years. But in the surveyed regions, though there is a decline in the acreage of sorghum and millet, there is an increased use of proprietary hybrids (hybrids by nature require less area but more productivity). As suggested in the section about variety release, privately released finger millet varieties are not evident in farmer's fields,

and none are available for other minor millets, such as foxtail or small millet. Varieties released by international agricultural research centers and other public agencies consisting of pure-line selections from local varieties of finger millet are popular among farmers.

The adoption rates vary from state to state. In the case of Karnataka, in the irrigated regions, the adoption rate of improved cultivars of finger millet is up to 50 percent (GOK 2004) the rainfed or semi-arid/arid regions of the state, still the traditional cultivars dominate the adoption (nearly 90 %).

4. CURRENT CHALLENGES

FARMER- SAVED SEEDS

The partnerships between national and international research systems over the last two decades did play an important role in the development and increased adoption of high yielding varieties of sorghum and pearl millet in India. Nearly 90 percent of the seeds used by farmers annually are saved from the preceding season, however (SAI 2002). This figure reflects, of course, both the reproduction system of the crop and its improvement status. Improved open-pollinated varieties in particular (such as Green Revolution and post-Green Revolution varieties of rice and wheat) need not be replaced as frequently as hybrids to maintain their yield advantages.

Among millet crops, farm-saved seed is more prevalent in sorghum and minor millets. In the case of sorghum, the principal reasons for the persistent use of farmer-saved seeds are 1) the availability of more improved open-pollinated varieties than hybrids, and 2) the recent increase in sorghum acreage in the post-rainy season, which is dominated by traditional cultivars (AGROSTAT 2002-03).The household survey data reinforces this conclusion. Findings presented in the previous two discussion papers revealed that only two (traditional) varieties of

sorghum, Maldandi and its improved selection M-35-1, still occupy nearly 90 percent of the sorghum area during the post-rainy season. Furthermore, the cultivation of post-rainy season sorghum, and hence the genotypes, are unique to India. In the case of minor millets such as finger millet, little millet and fox tail millet, there are hardly any improved cultivars available (except a few improved, pure-line selections from traditional types of finger millet) and local cultivars remain the only source of planting materials. During the rainy season, nearly 95 percent of the seed materials for minor millets and 75 percent of the improved open-pollinated varieties of sorghum and pearl millet were farm-saved. Farmers cited several reasons for the continued prevalence of open-pollinated varieties or sorghum and pearl millet (and hence, saved seed) during the rainy season. Sometimes, the onset of the monsoon is late and saved material is accessible and doesn't incur a cost. In other case, there is a consumption preference.

The extent of farmer-saved seed and the opportunities farmers have to re-use or re-sell saved seeds undercut the ability of seed developers (be they small-scale, firm operations or larger scale commercial entities) to recoup the cost of R&D. If saved seeds were used only by the farmers who originally purchased the seeds, seed developers could take this into consideration and set seed prices accordingly. In contrast, if farmers can sell seed, competition among sellers would drive seed prices to equal their marginal reproduction cost (net of the costs of invention), thereby eliminating the possibility to recoup R&D costs (Kremer and Zwane 2003; Koo et al. 2003). The survey data documents the propensity of farmers to exchange materials and purchase seed in local shandies in small quantities.

R&D ACTIVITY

Most of the private firms and the domestic public agencies in India still rely heavily on ICRISAT for their parental lines. Based on interviews conducted during field days held at

ICRISAT over the five years 1997-2002, private firms seem more interested in acquiring parents with high yielding potential than other traits such as pest and disease resistance. The grain yield potential in the resistance groups is inferior to that of high grain yield and boldness and other race-based groups. Table 8 provides some evidence on the interests of private and public institutions in millet crop improvement in recent years.

Table 8--Breeding materials requested by private and public sector from ICRISAT, 1998-2003.

Group	Private	Public
	(Percent)	
Resistance attributes[a]	8.5	15.2
Yield attributes	46.5	29.8
Total	55.0	45.0

Source: ICRISAT (2002-03).
[a] Denotes pest and disease resistance characters.

During our discussions with private company representatives, most of the firms agreed that the primary focus of their varietal development efforts in millet crops is geared towards the rainy season market which is dominated by high-yielding cultivars. The seed traders we interviewed during January-February 2004 felt that over the past 5-10 years the portfolio of public and private millet varieties available to farmers has expanded considerably. Around 95 percent of these cultivars are high yielding types, with short duration varieties particularly suited to the main rainy, irrigated season. For sorghum, only three out of 22 companies surveyed conducted any research on post-rainy season varieties and only five companies were developing pest resistant varieties. Still, there is a gap in terms of R&D activity between millet crops and

seasons. Discussions with representatives from private and public sector on the future of millet crops in India and their related research have highlighted the following considerations:

RAINY SEASON

The seed market for sorghum in the recent years especially during the rainy season is very competitive, represented by numerous agencies (both private and public). This also has increased the portfolio of varieties available to the farmers. The companies we interviewed expressed the point of view that the potential for further crop improvement especially for grain purposes is limited. They foresee considerable scope for creating either exclusive fodder or dual purpose (i.e., food and fodder) sorghum varieties suitable for the Indian market.

Almost all of the private companies focus most of their pearl millet research on hybrids (three-way crosses) rather than open-pollinated varieties because of the higher profit margin involved. In the Southern Indian states of Tamil Nadu, Karnataka and Andhra Pradesh, the scope for pearl millet expansion is limited to irrigated areas only. New markets for pearl millet are emerging, especially in parts of Maharastra and Gujarat. Company representatives further emphasized that in many of the dryer regions there are few if any substitute crops available to replace pearl millet especially during the summer months (February to June) in the western and northern parts of India, and so the demand for new pearl millet varieties over the next few years appears unlikely to diminish. For instance, almost all the major private firms in India have sought to develop cultivars resistant to downy mildew in pearl millet apart from developing hybrids suitable for the summer months; i.e., early maturing varieties to utilize the summer rainfall effectively. Pioneer Hi-Bred, JK Agri-genetics, Mahyco and Proagro seeds have invested nearly 3 to 5 percent of their total research budget exclusively on pearl millet research using biotechnology tools. As these states increasingly specialize in livestock farming, pearl millet

cultivation seems to be an inevitable and irreplaceable cropping choice, especially during the summer months. Pearl millet apart from being used as a food crop, largely used as a fodder especially during the summer months in the desert (arid) regions of Rajasthan and Gujarat.

POST-RAINY SEASON

Recent statistics reveal a decline in millet area, production and consumption in the primary millet growing regions of India during the rainy season, largely due to competition from other high-value crops such as maize, cotton and soybean. Both public and private seed supplies recognize that the area under post-rainy sorghum is increasing in the states of Karnataka and Maharastra and offers more scope for investment. For instance, Pioneer Hi-Bred Seeds in India has developed two sorghum hybrids (*Pi- 8703* and *Pi- 8704*) exclusively for post-rainy season growers. They are currently under field trials with plans to market the variety during the 2005 cropping season. These two hybrids are expected to yield 30 percent more than *Maldandi* and with one or two supplemental irrigation, the yield increase is around 50 percent over the existing cultivars (Personal communication with Pioneer Hi-bred marketing manager, January 12th 2003). The company hopes to cover 20,000 hectares in the states of Karnataka, Andhra Pradesh and Maharastra in the next four years. Other seed companies like JK agri genetics and Proagro seeds have also engaged in post-rainy season sorghum research. Some public research institutions are active in developing post-rainy season sorghum varieties. The University of Agricultural Sciences at Dharwad has released a high-yielding variety *(DH-4)* suitable for the post-rainy season.

MINOR MILLETS

The minor millet crops such as finger millet, little millet and foxtail millet do not occupy the prime irrigated agriculture areas. Compared with the major millets like sorghum and pearl

millet, the harvesting and processing of minor millets is extremely labor-intensive and so the crop is more prone to bird damage. Fodder yields are also higher for the modern varieties of major millets than the minor millets. Though the area under minor millets is limited to certain states of India, these crops still play a significant supplementary role in dryland farming systems especially the demand for minor millets is very niche based and specialized from emerging health foods sector in urban markets. Notwithstanding efforts made at the national level to collect germplasm material for the minor millets, the research intended to improve this crop is negligible. Moreover, the national area and production statistics for minor millets are also poorly compiled, grouping minor millets among coarse cereals for reporting purposes. ICRISAT and International Plant Genetic Resources Institute (IPGRI) along with national and non-governmental organizations have made efforts to document the diversity among these crops and have included finger millet in its research mandate from 1998. Still, other minor millet crops have received little attention in the research mandate of national as well as international research institutions.

PUBLIC-PRIVATE PARTNERSHIPS

In 2000-01, ICRISAT developed a new kind of partnership called a ‘consortium’ model, whereby private companies jointly fund research with ICRISAT to develop parental lines that are made publicly available. Initially, 14 private seed companies pledged a total of $109,000 annually to the consortia that supports applied plant breeding research at ICRISAT. The consortia at ICRISAT formed between the interested private seed firms who want to utilize the research facilities (such as biotech infrastructure and tools) along with parent materials and gene pool from ICRISAT. The research agenda is jointly decided by the consortia members. The motivation of private sector is very obvious in a way they can access the latest technologies,

genetic materials, and inbred lines which are offered from the ICRISAT's side. The materials developed through this consortium will be free for access for public organizations i.e., the consortium does not preclude public organizations from accessing ICRISAT materials and technologies. However in the case of private firms, inorder to gain access to the ICRISAT materials, the firms must be a member of the consortium.[12] Companies engaged in this consortium include international corporations (e.g., Avesthagen, Bayer Crop Sciences and Bio Seeds) and a large number of domestic seed companies (e.g., Advanta India, Cosmo, Ganga Kaveri, Hindustan Lever, J K Agri-Genetics, Mahendra Hybrids, Mahyco, New Nandi, Plantgene, Proagro, Prabhat Agri Biotech, and Shriram Bioseed Genetics).

As of March, 2004, 13 seed companies supported variety improvement research on sorghum as part of the consortium, 16 companies supported pearl millet research, and two companies contributed to pigeon pea research. The research focuses on diversifying the genetic base of these three crops to reduce vulnerability to diseases and pests, improving seed quality, and field testing of promising hybrids. The consortium also provides assistance to other Indian private sector companies in dealing with the regulatory process for transgenic crops. In this regard, ICRISAT is expected to play a much stronger role as an intermediary, particularly regarding assessment of the benefits and real risks of transgenic crops. A biotechnology-assisted plant-breeding consortium was deemed of substantial benefit to smaller companies unable to raise sufficient investment capital to establish their own autonomous research units.

INTELLECTUAL PROPERTY RIGHTS (IPR)

The Government of India enacted the Protection of Plant Varieties and Farmers' Act (PPVFR) in 2001 to meet the *sui generis* requirements of the country's WTO commitments

[12] Elicited from recent discussions of Dr.David Spielman with ICRISAT Consortium members, during February-March, 2006.

under the TRIPS agreement. *Sui generis* is a term literally meaning "of its own kind" or "unique". Systems for plant variety protection that are taken to satisfy the *sui generis* requirements of TRIPs are often called Plant Breeders' Rights (Koo et al. 2004). The Indian IP legislation recognizes the contributions of both plant breeders and farmers and thus it is unique in the world. It is different from the International Union for the Protection of New Varieties of Plants (UPOV) Convention that forms the basis of *sui generis* system in many other countries. For instance, re-use of farm-saved seed is provided as a farmer's right rather than as an exemption or as a privilege. The Act includes other features concerning the provision of community rights by means of benefit sharing mechanisms, the creation of a national gene fund, the inclusion of 'transgenics' as a part of definition of 'variety,' and extended protection of 'extant' varieties. The act has yet to be implemented, and its impact is open to speculation.

Research by Pray and Ramaswami (2001) and Pal and Tripp (2002) suggests that IPR legislation will improve private sector participation by providing clear mechanism for companies to protect their varieties from their competitors, thus providing incentives for the research efforts.

The private company representatives of large - and medium-sized companies we interviewed during January-February 2004 also repeatedly emphasized the need for stronger plant variety protection systems. They noted that stronger IPRs would reduce the share of low quality seed materials (with fake brand names) and thus improve the overall quality of seeds available in the market by curbing the operations of *'fly-by-night operators'*. Theft of parental lines, foundation seeds (by contract growers) and the sale of counterfeit seed are some of the threats to the intellectual property of a seed company (Shiva and Crompton 1998; Srinivasan 2002). Smaller seed companies were skeptical about stronger protection because many of them exploit particular niches or specialize in certain aspects of seed provision (Tripp and Pal 2001).

Pray and Basant (1999) reported that even with PVP, the inability to restrict farm-saved seed would be a major disincentive to the initiation of any major breeding programs for the Indian market.

In his survey of private sector seed companies, Srinivasan (2002) concluded that the response of the private sector to the Indian PVP legislation is likely to be unenthusiastic because the legislation is not seen as being oriented to improving returns on plant breeding investment. He attributed this to three problems. First is the complexity of the administrative procedures involved in its implementation. A second is the fear of the private sector that the benefit-sharing mechanisms intended to reward farmers as conservationists would diminish appropriability and reduce incentives for research. The third is that companies are not optimistic about effective enforcement of breeders' rights. Hence it is expected that the private sector will stay focused on hybrids as they have had inbuilt protection associated with its development.

Butler and Marion (1985) concluded that the private sector stimulus resulting from US PVP legislation enacted in 1970 was limited, at best. However, their study was conducted just over 10 years after PVP legislation came into effect in the U.S., a time period that may have been insufficient to capture the effects of the legislation on private sector plant breeders. A study by Pray (1992) of plant breeders' rights legislation in Argentina and Chile finds that PVP-style incentives had a significant and positive affect on private wheat breeding in all countries but Chile. He concludes that IPRs are a necessary, but not sufficient, stimulus to the transfer of agricultural technology and private sector investment in plant breeding; and that enforcement systems are as important as legislation. Further findings from studies conducted in high income economies also cast doubt on the innovation and productivity impacts of stronger IPR regimes (Perrin, Hunnings and Ihnen 1983, Lesser 1997, and Alston and Venner 2002).

There is also been concerns about the impact of proliferating IPRs on the freedom to operate and ability to generate new varieties. Problems with a tragedy of the anti-commons have been raised with too much property rights limiting innovation (Ramanna and Smale 2003). In their global appraisal, Koo et al. (2004) predicted that the Indian Act will benefit public over private interests and concluded that the effect of changing intellectual property regimes on new plant varietal development and dissemination, especially in the developing world, is yet to be seen. It is noteworthy that few propositions under the PPV & FR act are incorporated under the proposed new *Indian Seeds Bill* in 2004. Harmonization between the provisions under PPV&FR (2002) and the new seeds bill (2004) regarding farmers' right to retain and sell seeds to other farmers is questioned widely by farmers associations and non-governmental organizations. The new seeds bill and PPV&FR does have provisions for farmer to farmer sales of 'traditional or land races' but it is restrictive of re-sale of proprietary or public-bred varieties, without proper labeling should be truthfully labeled). The proposed PPV&FR legislation in most parts is in accordance with the interests of national and international agricultural centers. Certain areas are still under debate, such as the implementation or the implications due to Farmer's Rights (FR), breeders' rights and benefit sharing mechanisms. For instance, ICRISAT and other CG centers already have material transfers' agreement (MTAs) in place, which assure free access to public varieties and materials. Private firms are still skeptical about MTAs since they fear that this would limit their 'free access' to genetic materials.

5. CONCLUSIONS

To better understand the evolving interactions between formal institutions related to the delivery of modern variety of seeds and informal systems for maintaining traditional seeds,

interviews were conducted with various actors in the millet seed system. In the third of three papers, findings from personal interviews with seed sector representatives and analysis of secondary data about the national seed industry were presented. A total of 22 private seed company representatives of various sizes (small, medium and large) were contacted to elicit information regarding millet production, marketing and research.

The establishment of the International Crops Research Institute for Semi-arid Tropics (ICRISAT) in 1972 enabled the wider exchange of germplasm around the world and spurred the millet crop improvement efforts in India, supporting the development of the private seed sector. Changes in India's seed regulations during 1990s favored the growth of privately- as compared to publicly-funded sectors. The increasing presence of multinational companies either in partnership with existing domestic seed companies or operating on their own is evident in recent years. Most advances have been made in the major millet crops, sorghum and pearl millet, as compared to finger millet and other minor millet crops. Though the share of proprietary hybrids in sorghum and pearl millet has grown tremendously in the past decade, publicly-bred sorghum hybrids continue to occupy a major share and the share of sorghum OPVS has grown.

Our survey also indicated that the R&D efforts of large seed firms is much more pronounced than medium sized firms and research capabilities of small firms hardly exist, especially for millet crops. The preference of hybrids over open-pollinated varieties among commercial seed companies is centered on profit. Detailed comparisons of marketing margins among different actors in the seed supply channel also confirmed that seed producer margins and price spreads were highest for private hybrids of pearl millet, followed by public hybrids of sorghum and private hybrids of sorghum. The analysis further showed the key role played by 'dealers' in local markets in supplying information and seed material in drylands of India.

Cumulative adoption rates for major millet crops over the last four decades shows that the higher adoption of high-yielding varieties were more pronounced in irrigated and favorable regions of India, especially for pearl millet and sorghum. For minor millet crops, varieties released by state agricultural universities that consist of selections from local germplasm are popular among the farmers.

IMPLICATIONS

Current challenges facing the millet seed sector in the marginal environments of India are three fold: a) the extent and persistence of farm-saved seeds. b) variation in R&D investment across seasons and millet crops; and c) seed sector regulations, in particular the enactment of recent plant variety protection and farmers' rights legislation in India. The extent and continued use of farm-saved seeds especially in case of minor millets and post-rainy sorghum on the one hand discourages the entry of commercial sector in developing new research products and also from the perspective of public sector to add any kind of incentives for their already existing research. Though farm-saved seeds promote the use of local or traditional varieties to some extent thus conserving the land races, over time it doesn't provide adequate choices to the farmers to diversify their portfolio and thus improving productivity. For example, the success of millet seed sector development in India is mainly attributed to the combined efforts of public (national and international) and private sectors. With the recent enactment of the Protection of Plant Varieties and Farmers' Act (PPVFR), various stakeholders involved in the seed system have expressed concern regarding the re-use of seeds (including protected varieties), incentives for research, benefit-sharing mechanisms for farmers' varieties and implementation of farmers' rights. The hybrids as such as have inbuilt protection as it discourages re-use of seeds. In the case of OPVs especially for crops like minor millets where the heterotic vigor is not exploited

fully, it is important to address the issues of 'variety protection'. This becomes important particularly in maintaining the quality of seeds and thus avoiding spurious seeds.

With changing consumption preferences among food crops (towards rice, wheat and corn) in the recent years, the area under millet crops is declining in India. Research investment in improving dry land crops improvement is also declining, whether privately or publicly funded. To improve millet crops, it will be necessary to explore innovative partnerships between private and public entities. Most of the millet germplasm is in the public domain, while private firms have greater investment capability along with more efficient seed supply mechanisms and marketing networks. To effectively utilize the expertise in both sectors, ICRISAT in the year 2001 formed a 'research consortia' whereby private companies jointly fund research with ICRISAT to develop parental lines that are made publicly available to the consortia members.

The drought resistant features of the millet crops make them ideally suited for cultivation in the semi-arid tropics, especially as a cropping option in the post-rainy season. Substituting scientifically bred millets and sorghum for farmer-bred varieties has realized sizable yield gains over the past several decades in the rainy season. Similar gains have largely eluded millet crops planted in the post-rainy season and for minor millet crops. Although the research commitment has been small, conventional breeding efforts have so far failed to improve yields; perhaps modern bioengineering techniques may prove more useful (Mahyco 2004). Until then, dry season farming in areas of India like Andhra Pradesh and Karnataka will remain heavily reliant on a comparatively narrow base of bio-diversity. A single sorghum variety (Maldandi and its selection M-35-1) dominates with few if any options to diversify to other millets or other crops. Indeed, the successful introduction of new millet varieties into this production system could dramatically increase the diversity found in these farmers' fields.

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ANNEXES

Annex 1--Chronology of major seed-related laws and regulations enacted in India

Type	Date enacted	Notes
I. Seed regulations, institutions and quality control		
National Seeds Corporation	1963	Responsible for promoting seed industry development from production through processing, storage and marketing, and establishing a system of quality control through seed certification.
Seed Act	1966	This act provided a system for seed quality control through independent state seed certification agencies that were placed under the control of state departments of agriculture.
Seed Rules	1968	To give effect to the provisions of Seeds Act 1966, seed rules governing seed quality issues were framed.
State Seed Corporations (13)	1970-80	Established with the support from World Bank, for production and handling of seed in their respective states; to coordinate with NSC on seed procurement and sales price as well as variety demand and supply.
Seeds (Control) Order	1983	Enabled the Government of India to declare seeds as an essential commodity to bring all the crop seeds, whether notified or not, under regulation.
Department of Biotechnology	1986	Central agency, responsible for biotech policy, promotion of R&D and international cooperation and manufacturing activities.
New (Liberalized) policy on seed development	1988	Enabled the entry of more private sector participation in the domestic sector.
New Seeds Act	2002	Significant changes to the existing legislative framework to simulate varietal development in line with market trends and to introduce advanced scientific knowledge (including biotechnology) to meet farmers' needs. The emphasis on compulsory registration in the new seeds policy ties in with the demands of the PVP and Farmer's right act passed in 2001.

Annex 1--Chronology of major seed-related laws and regulations enacted in India (continued)

Type	Date enacted	Notes
II. Trade and Intellectual Property Rights		
World Intellectual Property Organization WIPO) convention	1967	WIPO seeks to: harmonize national intellectual property legislation and procedures, provide services for international applications for industrial property rights, exchange intellectual property information, provide legal and technical assistance to developing and other countries, facilitate the resolution of private intellectual property disputes, and marshal information technology as a tool for storing, accessing, and using valuable intellectual property information.
New Industrial Policy of India	1991	This policy identified seed production as 'high priority, sunrise industry'. The policy further liberalized import of vegetable and flower seeds in general and seeds of other commodities in a restrictive manner; also encouraged multinational seed companies to enter the seed business with 50 percent equity.
World Trade Organization membership (WTO)	1995	Deals with the global rules of trade between nations. Its main function is to ensure that trade flows as smoothly, predictably and freely as possible.
Trade Related Intellectual Property Rights (TRIPS)	1998-99	The WTO's Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS), negotiated in the 1986-94 Uruguay Round, and introduced intellectual property rules into the multilateral trading system for the first time.
The Plant Variety Protection and Farmers' Rights Act (PPVFR)	2001	This new legislation allows farmers to enjoy their traditional rights to save; use, exchange, share, and sell the produce of the protected variety with the restriction of not allowed selling braded seed of the protected variety.
Biodiversity Act	2002	Provides for the establishment of national biodiversity authority and state authorities with laid out rules and mechanisms on acquiring biological resources, material transfers for research and royalty provisions in the form of benefit sharing.
International Treaty on Plant Genetic Resources (ITPGR) - FAO treaty	2002	The objectives are the conservation and sustainable use of plant genetic resources for food and agriculture and the fair and equitable sharing of benefits derived from their use, in harmony with the Convention on Biological Diversity.
UPOV convention	-	Applied for membership in 2003-04.

Annex 1--Chronology of major seed-related laws and regulations enacted in India (continued)

Type	Date enacted	Notes
III. Phytosanitary Regulations		
Destructive Insects and Pests Act and Plants, fruits and seeds (regulation of import in India) order.	1914 &1989	The act and order regulate the import into India of agricultural products including plants and seeds. Prohibits import of seeds for sowing and planting without a valid permit; all imports should be accompanied by an official Phytosanitary certificate.
Biosafety Act	1986	This act provides rules for the manufacture, use, import, export, and storage of hazardous microorganisms, genetically engineered organisms or cells. All genetically engineered crops and varieties will be tested for environment and bio-safety before their commercial release.

Source: Compiled by the author from various sources including Koo et al. (2004), Smale and Ramanna (2004) and Pal and Tripp (2002).

Annex 2--Privately produced hybrid seeds in Andhra Pradesh and India, 2001-02

Crop	India	Andhra Pradesh	
	Quantity	Quantity	Share of seeds in total
	(metric tons)		*(percent)*
Maize	700000	600000	86
Cotton	55916	35167	63
Pearl Millet	150000	95000	63
Forage Sorghum	180000	175000	97
Sorghum	125000	116000	93
Sunflower	30000	25000	83
Paddy (Hybrid)	60000	48000	80
Okra	NA	2000	na

Source: Personal communication with President, Seeds Men Association of Andhra Pradesh (January 2004).
Note: There are 440 private seed companies (organized and unorganized) operating in the state, specialize in various crops.

Annex 3--Varieties grown by the households in the survey areas

			Improvement Status				Bred By		Pedigree Details[b]			Observed in		Season	
				Modern[a]											
Number	Variety Name	Release date	Traditional	OPV	IPLS	Hybrid	Public	Private	ICAR	ICRISAT	Others	K	AP	Rainy	**Post-rainy**
SORGHUM															
1	Allina jola		x									x			x
2	Bijapur jola		x											x	
3	Bili jola		x											x	
4	Csh-1	1965-66				x	x		x			x	x	x	
5	Csh-11	1990-91				x	x		x			x	x	x	
6	Csh-14	1998-99				x	x		x	x		x		x	
7	Csh-15	1997-98				x	x		x			x		x	
8	Csh-16	2000-01				x	x		x	x		x		x	
9	Csh-5	1975-76				x	x		x			x		x	
10	Csh-9	1985-86				x	x		x			x		x	
11	Dodda jola		x									x	x	x	x
12	Gangavati sorghum		x									x		x	
13	Gidda maldandi		x									x			x
14	Gunduteni		x									x		x	
15	Hala jola		x									x		x	
16	Hombale jowar		x									x		x	
17	Itc jowar	1992-93				x		x			x	x		x	
18	Jawari jowar		x									x		x	
19	Jk-5	1989-90				x		x		x	x	x	x	x	
20	Jk-22	1995-96				x		x		x	x	x	x	x	
21	Kenjola		x									x		x	
22	Kesari		x									x		x	
23	M-35-1	1980-81		x			x		x		x	x	x		x
24	Maldandi		x				x					x	x		x
25	Mugutheni		x									x		x	
26	Muguti maldandi		x									x			x
27	Msh-51	1990-91				x		x	x	x		x	x	x	
28	Nandiyal white		x									x	x	x	
29	Pac-501	1990-91		x				x		x	x	x	x	x	
30	Paras jowar	1992-93		x				x			x	x	x	x	

Annex 3--Varieties grown by the households in the survey areas (continued)

Number	Variety Name	Release date	Improvement Status				Bred By		Pedigree Details[b]			Observed in		Season	
			Traditional	Modern[a]			Public	Private	ICAR	ICRISAT	Others	K	AP	Rainy	**Post-rainy**
				OPV	IPLS	Hybrid									
31	Pioneer jowar	1994-95		x				x			x	x	x	x	
32	Proagro-296	1990-91		x				x			x	x	x	x	
33	Sorghum agro	1995-96		x			x		X		x	x		x	
34	Tella jola		x									x	x	x	
35	Vikarbad local			x							x		x		
36	Yaniger		x									x		x	
PEARL MILLET															
1	Local dwarf bajra														
2	Advante hybrid	1990-91				x		x		x	x	x	x	x	
3	Bajra kaveri	1993-94				x		x		x	x	x		x	
4	Bajra paras	1991-92		x				x		x		x	x	x	
5	Bajra agro	1989-90		x			x		x	x		x		x	
6	Bajra seedtec hyb.	1994-95				x		x		x	x	x		x	
7	Hybrid bajra mahyco	1990-91				x		x		x		x	x	x	
8	ICMV-221	1992-93				x		x		x		x		x	
9	ICTP series(5 lines)	1980-98		x					x			x	x	x	
10	Jawari bajra		x									x		x	
11	Jawari sajji		x									x	x	x	
12	Kaveri	1995-96		x				x	x	x		x	x	x	
13	Paras Bajra	1992-93				x									

Annex 3--Varieties grown by the households in the survey areas

			Improvement Status				Bred By		Pedigree Details[b]			Observed in		Season	
				Modern[a]											
Number	Variety Name	Release date	Traditional	OPV	IPLS	Hybrid	Public	Private	ICAR	ICRISAT	Others	K	AP	Rainy	**Post-rainy**
FINGER MILLET															
1	Annapoorna ragi	1990-91			x		x		x		x	x	x	x	x
2	Black ragi		x									x		x	
3	Dwarf ragi		x									x	x	x	
4	Farm ragi		x									x	x	x	x
5	Godavari	NA			x		x				x	x		x	
6	Gpu-22	1991-92			x		x		x		x	x	x	x	
7	Gpu-28	1996-97			x		x		x		x	x	x	x	x
8	Indof-5	1994-95			x		x		x		x	x	x	x	
9	Kalyani														X
		1992-93			x		x				x	x	x	x	
10	Pr-202	1990-91			x		x				x	x		x	
11	Short ragi		x									x		x	
12	V-20	NA			x		x		x		x	x		x	
13	White ragi		x									x		x	
LITTLE MILLET															
1	Black samai		x									x		x	
2	Hali samai		x									x		x	
3	Jawari samai		x									x	x	x	
4	Mallige samai		x									x	x	x	
5	Local samai		x									x	x	x	
6	White samai		x									x		x	
														x	

Annex 3--Varieties grown by the households in the survey areas

Number	Variety Name	Release date	Improvement Status				Bred By		Pedigree Details[b]			Observed in		Season	
			Traditional	Modern[a]			Public	Private	ICAR	ICRISAT	Others	K	AP	Rainy	**Post-rainy**
				OPV	IPLS	Hybrid									
FOXTAIL MILLET															
1	Hala Navane		x									x	x	x	
2	Local Navane		x									x		x	

Source: Field surveys conducted by L.Nagarajan during October 2002-June 2003, ICRISAT Gene bank, and ICAR Center for sorghum and finger millet, UAS, Dharwad and Bangalore (2003-04).

[a] OPV refers to open-pollinated varieties, IPLS refers to Improved pure-line selection.

[b] ICAR – Indian Council of Agricultural Research and ICRISAT- International Crops Research Institute for Semi-arid Tropics, Others include state agricultural universities and private sector companies.

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