Adoption and impact of technology on Pearl millet Production in India: Farm and Regional Level ex-ante and ex-post impact analysis*

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Introduction

In the arid and semiarid harsh environment, the cropping choice is restricted due to moisture stress, low soil fertility, poor and saline soils and lack of assured sources of irrigation. Dryland cereals like pearl millet and sorghum are the hardy and sturdy crops that thrive in such adverse agro-ecological situations and are less risky for production. Both millet and sorghum continue to occupy a prime place in small holder farming systems in arid and semi-arid regions providing employment, income and food for human consumption and feed for livestock. But at the same time, excessive dependence on rice and wheat for food self-sufficiency has not only made food security fragile, but also has shrunken the diversity of food basket. In order to alleviate this problem and to make food more nutritional, healthy and affordable, coarse cereals like pearl millet and sorghum deserve to be promoted specifically in the wake of climate change. Pearl millet is annually cultivated on nearly 30 million hectares across the arid and semiarid tropical andsubtropical regions of Asia, Africa and Latin America. It is a staple food for more than 90 million people who live in the drier areas of Africa and Asia (FAO, 2010). India is the largest single producer ofpearl millet, both in terms of area (9.3 million hectares) and production (8.3 million tons). In India, more than 70 % of the pearl millet area is accounted by 3 states viz., Rajasthan, Maharashtra and Gujarat. In terms of production share, Rajasthan, UP and Gujarat accounts 77 % of the total produce (Nagaraj, 2012).

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Genomic technologies and tools have advanced rapidly in recent years and are being widely applied in improving the productivity of dry land cereals by both public and private sectors leading to emergence of several improved cultivars/hybrids for commercial cultivation. Thus, it is imperative to analyse the extent of adoption, the incremental benefits of improved technologies and the impacts of technologies on productivity gain. The specific objectives of this study include:

- Analysis of levels of adoption of improved cultivars/hybrids of pearl millet across different states
- An ex-ante analysis of potential benefits of improved technologies at farm level and ex-post impact of improved technologies at regional level
- Exploring the policy options to stimulate growth in the pearl millet demand

Methodologies

Information relating to documentation of available and potential technologies for pearl millet has been elicited through review of literature, secondary data, baseline studies of the HOPE project records, focused group meetings, consultancy report on the impact evaluation of HHB 67 Improved, interactions with scientists and farmers. The ex-ante impact of available crop technologies has been estimated considering the improved interventions and their respective adoption rate in the adopted cluster villages of Rajasthan, Gujarat and Haryana under HOPE project (Harnessing Opportunities for Productivity Enhancement in South Asia). Economic indicators were estimated based on annualized research costs, incremental benefits decided as the difference in the benefits between local and HHB 67 Improved and adoption rate (area under HHB 67 Improved). The benefits from HHB 67 Improved started flowing from 2006 to 2011, while investment phase was during the period 1999-2005. Both benefits and costs were discounted in order to bring to the present values considering discount factor of 5%. The net benefit for each year was obtained by taking the difference in the total discounted returns and costs. The standard discounting cash flow measures of Internal Rate of Returns (IRR), Net Present Worth (NPW) and Benefit Cost Ratio (BCR) were computed

Review of literature

The econometric estimation by Matuschke and Qaim (2008) identified three factors that contributed to the adoption of pearl millet hybrids over recent decades viz., education level of farmer, distance to the main source of information, and good market infrastructure. In addition, the increasing role of private companies in seed development and distribution had a positive effect on innovation rates. The study refutes the notion that privatization of seed markets would hamper technological progress in the small farm sector, and suggests that even in typical subsistence crops, such as pearl millet, the private sector can play an important role.

Popular public hybrids such as HHB 67 (released by Haryana Agricultural University in 1989) delivered increased production levels from the early 1990s until now with current production at 9 million tons. Currently, hybrids cover more than 50 percent of the total national pearl millet area of 24.7 million acres (Thakur et al. 2003).

A case study of two hybrids of pearl millet was carried out by ICRISAT in the year 2006 to document the impact of ICRISAT-derived breeding materials on the consortium partners. Two of the leading private seed companies (JK and Pro Agro (Bayer crop science)) had developed successful hybrids of pearl millet of ICRISAT-bred A-lines (or their sub-selections), by exploiting their residual variability. The hybrid JKBH 26, developed by JK Agri Genetics, is based on an A-line that has no other hybrid, public or private, on the market. This hybrid has been under cultivation since 1996, retaining its initial high level of downy mildew resistance. The hybrid was adopted by increasing number of farmers for its high grain and stover yield as well as its high level of downy mildew resistance, reaching a peak adoption level of more than 400,000 ha in 2005 in India. The hybrid 9444 was developed by Proagro Seed Company (now Bayer BioScience). It is also highly valued for its high grain and stover yield, good stover quality (farmers' perception), and downy mildew resistance. This hybrid is also highly tolerant to

temperatures as high as 45°C during flowering time. The adoption of this hybrid rapidly increased from 60,000 ha in 2001 to more than 400,000 ha in 2006. (Mula et al. 2007)

Pray et al. (1991) and Pray and Ramasami (2001) summarized the factors in making hybrid seed of pearl millet and sorghum widely available in India. They include: 1.Government/ICRISAT research programs produced the high-yielding varieties and hybrid parental lines. 2. Seed industry development programs of the National Seed Corporation (assisted by the Rockefeller foundation and USAID) trained companies in producing quality, foundation, and certified seeds during the early 1970s. 3. Private companies multiplied seed and sold it to farmers using wider market networks.

Adoption of Improved pearl millet hybrids:

Figure- 1 shows at all India level, the adoption of improved varieties/hybrids have been increasing steadily since 2002 (Increasing at the rate of 2.5 % per annum). State wise percentage of pearl millet area coverage with high yielding varieties and changes over time, is provided in the table-1. As discernible from the table, adoption rates are relatively low in the states of Rajasthan, UP, MP, Karnataka and Maharashtra due to non-availability of quality seeds. It is 100 % in Gujarat and Tamil Nadu and more than 70 % in Haryana and AP. Because of seed production problems in the public sector, the private sector played a vital role in certified seed production and delivery targeting high input use area with supplemental irrigation in the states of Gujarat, Haryana and Rajasthan. However, public sector is focussing more on harsh agro climatic ecologies with low input use intensity coupled with vagaries of rainfall. Hence, in the states of Gujarat and Haryana, almost 80 % of the pearl millet area is occupied by hybrids/ HYV's with privately bred cultivars (Pray and Nagarajan 2009). The improved cultivars popularised among the farmers in western parts of India because of good grain and fodder quality along with resistance to abiotic and biotic stresses like disease-pest infestation, draught, heat wave and so on. The factors influencing adoption of pearl millet varieties *inter alia* include short duration, productivity, grain and fodder quality, drought resistance, disease and pest resistance.Thus,

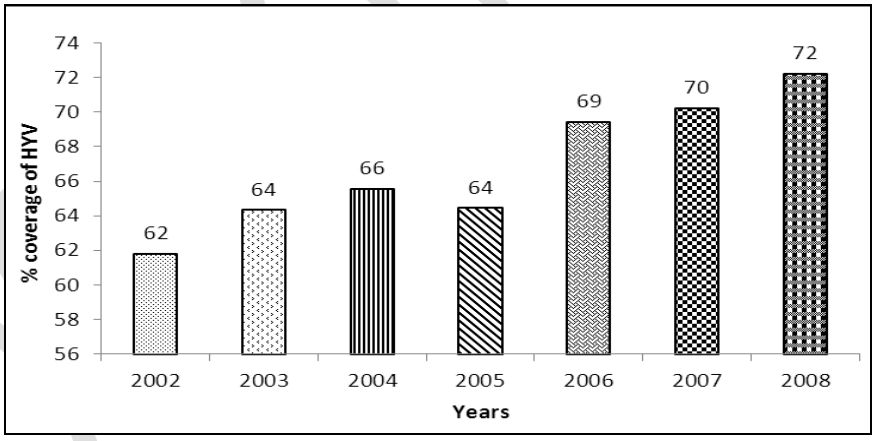
farmers have adopted improved cultivars and reduced their risk due to availability of early maturity, high yielding varieties with easy accessibility.

Table 1: Coverage (% of total area) of pearl millet high yielding varieties in major states of India

	2000	2001	2002	2003	2004	2005	2006	2007	2008
Rajasthan	24	31	32	32	35	37	40	42	45
Maharashtra	50	59	63	65	65	68	70	70	72
Gujarat	87	95	92	100	100	100	100	100	100
U.P	14	22	26	35	36	40	42	45	50
Haryana	58	63	66	67	70	72	75	75	75
Karnataka	49	56	59	60	62	65	65	65	68
A.P	77	86	85	85	86	88	88	90	90
T.N	72	95	100	100	100	100	100	100	100
M.P	30	32	33	35	36	40	45	45	50
India			62	64	65	68	69	70	72

Source: AICPMIP, Jodhpur, Rajasthan 2010

Figure1. Crop area coverage of pearl millet from 2002 to 2008 high yielding varieties / hybrids at all India level



Area, Production and Productivity Trends

Pearl millet area and production at all India level increased till 1970's but decelerated during 80's (figure-2). This was mainly due to downy mildew epidemics. In fact, the area has attained peak during 1970's, after 1980's, there was a decline in area under pearl millet recording negative growth rate (table 2). Though there was a negative growth rate in the area, accelerated productivity sustained

production thereafter. The reduction in pearl millet crop area is partly due to frequent droughts and also lack of economic incentives and effective demand. The productivity of pearl millet triggered appreciably at the rate of 8 % per annum. In most of the states in India, the trends in area, production and productivity of pearl millet witnessed three waves of change. The 1st wave pertained to pre green revolution period (1950 to 1960's), the 2nd wave was in green revolution period (1970's to 1980's) and the third wave in post green revolution period (after 1990's) (figure 2).

Figure.2Area, production and productivity trends during different periods

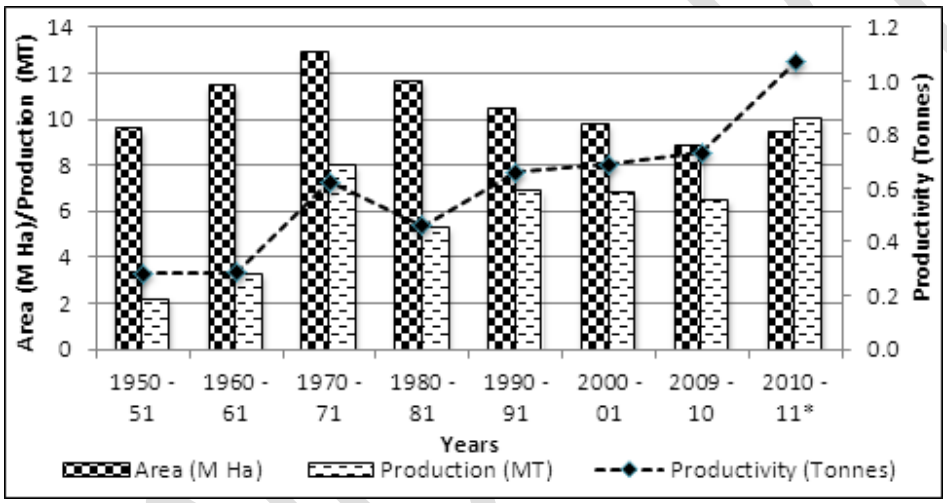


Table 2. Growth rate of Area Production and Yield of pearl millet in India (%)

Period	Area (M Ha)	Production (MT)	Yield (Kg/ha)
1950-60	2.43	2.35	-0.07
1960-70	1.19	9.37	8.08
1970-80	-1.01	-4.00	-3.01
1980-90	-1.06	2.58	3.69
1990-2000	-0.64	-0.19	0.45
2000-10	-0.41	4.08	4.51

During the pre-green revolution period, traditional varieties were grown hence the growth in output was driven by area expansion.During the green revolution period, there was appreciable increase in productivity due to high yielding varieties and hybrids, intensive use of chemical fertilizers and other improved package of practices. However, owing to frequent outbreaks of downy mildew the yield

stagnated during early 80's, and the productivity recorded a negative growth rate of 3 % per annum. Again the productivity rebounded during the mid-1980's with the release of hybrids with the assistance of ICRISAT which were resistant to fungus. Thus, in the second wave of change, the growth in output was mainly productivity led due to technical change with access to markets. The third period marked by release of varieties with value added attributes like resistant to pests and diseases, drought and heat tolerant. In this period too, area exhibited declining trend but productivity increased at a higher rate as evident from the table 2.

Synergies from the public and private investment on sorghum R and D-Implications

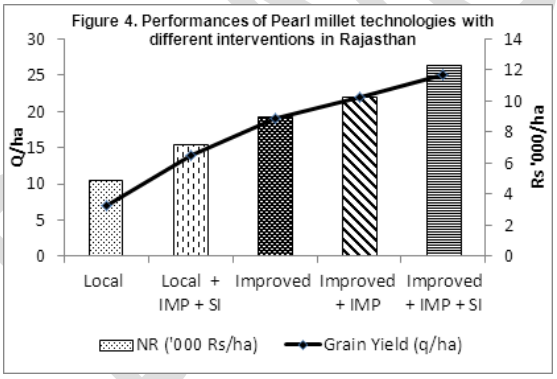
Till 1990, the public sector, primarily national and state governments, monopolized investments in agricultural R & D, especially on food crops. The new technology led interventions were implemented by national and state governments working in collaboration with the International institutes like International Crop Research Institute for the Semi-Arid Tropics (ICRISAT). The ICRISAT contributed genetic material to public and private institutions that helped to breed varieties resistant to biotic and abiotic factors. Using ICRISAT germplasm and breeding materials, as of December 2010, 242 sorghum and 163 pearl millet varieties/hybrids have been released by NARS (http://www.thehindubusinessline.com/industry-and-economy/agri-biz/article2047506.ece). These research institutes mainly focused on breeding varieties that are resistant to pests and diseases, but seed production takes place by both public and private sectors. Additionally, favourable government policies also encouraged private investment on seed multiplication and distribution. Currently, at all India level, 82 % of the total seed supply of pearl millet and 75 % of the sorghum is by private sector companies (Pray and Nagarajan 2009).

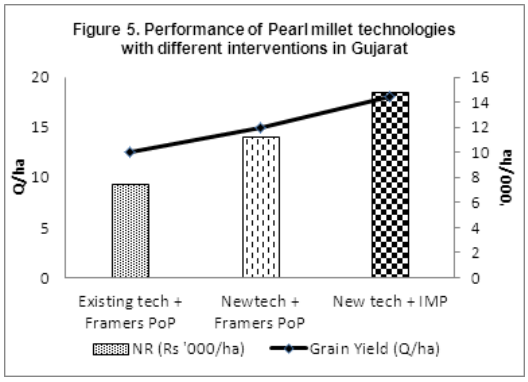
Due to public private partnerships in the key areas of research in terms of developing varieties, production and delivery of improved seed, coupled with outreach activities enabled to increase seed replacement rate phenomenally, and then productivity of pearl millet increased manifold benefiting

farmers. The increased productivity enabled farmers to allocate less area under millets and divert the saved land to other cash crops, improving the additional income to the farmers. Thus, the major impacts include remarkable increase in the productivity from 2. 9 qtls per ha to 10.7 qtls per ha - an increase of five fold between 1960 to 2010. Due to high productivity, there has been saving of land. The unit cost of production has also fallen from 1999 and 2003 in Rajasthan due to enhanced productivity from Rs. 174 to 105 per qtl (http://eands.dacnet.nic.in/costofcultivation.pdf).

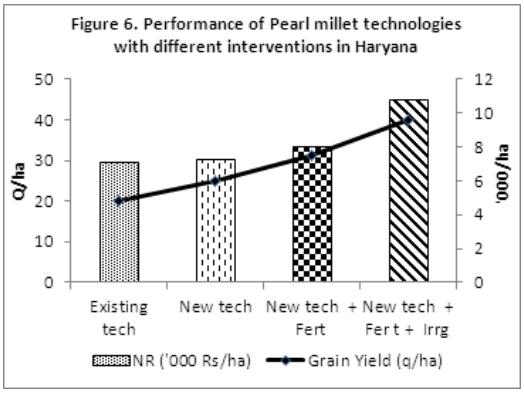
Ex-ante analysis of frontier technologies

Besides targeting improved varieties, targeting on management practices like drilling of fertilizer along with seed, seed treatment, deep sowing, wide row spacing, optimum plant population, Integrated Pest Management (IPM) and Integrated Nutrient Management (INM) are crucial to augment productivity. The ex-ante analysis of some of these technologies were carried out from the case studies in 3 states viz., Rajasthan, Gujarat and Haryana village clusters, where pear millet is predominantly cultivated. The key results are represented in Figures 4, 5 and 6.





In case of Rajasthan, the net returns doubled from Rs. 4870 to Rs. 10300 with the adoption of improved variety plus the improved management practices in the selected cluster villages. However with supplemental irrigation, the net returns increased by another 20 %. Similarly, in case of Gujarat, the net returns doubled with the adoption of improved cultivars and improved management practices. In case



of Haryana, the increase in net returns is very modest (from Rs. 7063 to 8063), an increase of 15 %. This is due to the fact that the local pearl millet varieties are completely disappeared, and the private and public hybrids are in vogue. Hence, the incremental returns in response to different interventions are modest. The productivity levels have been very impressive with the adoption of different technological interventions at cluster level as evident from the Figure 4, 5 & 6.

Impact assessment

HHB-67, a public-bred hybrid was developed and released by HAU in 1995-96 was widely adopted by farmers in Haryana and Rajasthan, covering over 400,000 hectares. The Key advantages are a) best suited for low rainfed ecosystems, b) short duration allowing taking second crop like chick pea and d) highly downy-mildew resistant. Selection of HHB 67 Improved has made rapid transformation in pearl millet cultivation practices and total pearl millet acreage in North-west India. Farmers preferred HHB 67 Improved over locals and other hybrids due to its ability to tide over erratic and undependablerainfall in Rajasthan and Haryana. In the survey farmers reported that HHB 67 Improved was planted in 60 % of the pearl millet area followed by locals (30 %) and other hybrids(10 %), by small and marginal farmers of Rajasthan . In case of medium and large farmers, HHB 67 Improved covered (45 %) and other hybrids (42 %), while local varieties accounted for 10 %. In case of Haryana, HHB 67 Improved hybrid covered 60 % of the total pearl millet area of small and marginal farms, while the remaining 40 % by other proprietary hybrids. In case of medium and large farms 84 % of the area was planted to HHB 67 Improved. Since HHB 67 Improved, being early, permitted them to cultivate a second crop in early *rabi* (Harinarayana, et

al (2012). An attempt is made here to evaluate the impact of HHB 67 on productivity gains using the data from Rajasthan and Haryana states and the results are given in the table 3.

Table3. Economic measures of Investment analysis on HHB 67 Improved

Economic Measures	Rajasthan	Haryana
Area coverage ('000ha)	791.5	204.0
NPV (Million Rupees)	399.2	123.2
IRR	0.35	0.46
BCR	1.31	1.32

Source: Harinarayana, et al (2012).

The cumulative net present value of benefits from research from HHB 67 Improved pearl millet in Rajasthan to the farming community is about Rs 400 million, which works to Rs. 4 million per annum at 5 % rate of discount considering 10 years of time horizon. The IRR is 35 % indicating that the marginal efficiency of investment in R and D is substantial. In Haryana, the estimated NPV to farming community is Rs. 123 million or Rs. 1.23 million per annum yielding an IRR of 46 %. The discounted BCR is 1.31 in Rajasthan as against 1.32 in Haryana reflecting the investment on pearl millet research is economically viable.

Policy bias towards procurement and support prices against dryland cereals

Even though Minimum support prices are offered for dryland cereals similar to rice and wheat, farmers are not responding to millet cultivation due to (1) absence of procurement operations (2) lack of consumer demand as millets are treated inferior goods for consumption (3) poor value addition at farm level (4) poor consumer awareness and (5) lopsided policy support compared to rice, wheat and other commercial crops. Though MSP is announced for pearl millet, it is procured very rarely. Thus the MSP has become notional. Unless the price scenario changes, millet will not emerge as commercial crops and the area under pearl millet is likely to decelerate though the productivity may improve with the availability of improved technology.

Policy Bias of Public Distribution System (PDS) against dryland cereals

The rice and wheat has been distributed in PDS at subsidized prices for the people who are below the poverty line. This has substantially enhanced the consumption pattern of cereals, as the price of dryland cereals is much higher in local markets compare to the subsidized prices of rice and wheat. This change in consumption pattern adversely affected the growth and development of coarse cereals.

The Government must include millets in the PDS as a quid pro quo measure in the National Food Security Mission. Millets also need to be integrated with Integrated Child Development Services (ICDS), Mahatma Gandhi National Rural Employment Guarantee Act (MNREGA) and School Mid-day Meals programmes in regions wherever these crops are predominantly grown.

Value addition in millets is crucial to widen markets, especially to enhance consumer acceptance and to render cultivation of these crops to wider regions. Exploring non-conventional uses and extrusion products is another important area for future investment.

Conclusions

Pearl millet is predominately grown in arid and semi-arid regions of India under rainfed conditions and continues to play a prominent role in the dryland harsh agro climatic regions of India. Since the last four decades, improved cultivars occupied more than 70 % of pearl millet area under rainfed conditions. The adoption of frontier technologies' by the farmers has led to significant impact on improving productivity of pearl millet in most marginalised harsh agro climatic ecologies of India. The productivity of pearl millet increased appreciably from 2. 9 qtls per ha to 10.7 qtls per ha an increase of five fold between 1960 to 2010 due to genetically improvement, crop management and growing markets. Due to high productivity, there has been saving of land which has been allotted to other crops. The ex-ante analysis

indicated that with the adoption of improved cultivars along with management practices, the productivity and incremental returns doubled. The impact appraisal indicated that the productivity gain and the spread of benefits from hybrid cultivars is substantial as indicated by high NPW and IRR of 35 to 45 %. Furthermore, from the view point of small and marginal farmers, the hybrids are valuable as these farmers are completely dry land dependent and the hybrids ensure them some level of assured yield even in draught season. In order to stimulate demand for the pearl millet, value addition at micro and macro levels with technological support is crucial. There is a policy bias towards procurement and support price. In addition, pearl millet has been relegated as inferior cereal in spite of several advantages.

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