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Efficiency and Sustainability Gains from Adoption of Short-duration Pigeonpea in Nonlegume-based Cropping Systems

International Crops Research Institute for the Semi-Arid Tropics

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Abstract

This study establishes an important connection between farmers' concerns regarding sustainable farming and the adoption of improved technologies. Results from a formal on-farm survey and rapid rural appraisals conducted in a drought-prone area in Central India confirm that: (1) farmers are well aware of the effects of intensive cultivation of cash crops, such as sugarcane or cotton in irrigated tracts, in terms of reduced yields and increasing use of inputs; (2) appropriate crop/varietal adoption and management practices are consciously implemented to maintain long-term productivity levels for existing and desired cropping systems; and (3) farmers strive to increase or maintain soil fertility by including nitrogen-fixing legumes in crop rotations - in this case, short-duration pigeonpea. Widespread adoption of short-duration pigeonpea has made farming profitable in the short term - via cultivation of a second crop in the postrainy season - and farmers expect to sustain productivity in the long run via crop rotation to maintain soil fertility.

Résumé

Les gains d'efficacité et de durabilité résultant de l'adoption du pois d'Angole à maturation précoce dans les systèmes de culture à base de plantes non-légumineuses. Cette étude établit une liaison importante entre les préoccupations des paysans quant à la culture durable d'une part, et l'adoption de technologies améliorées de l'autre part. Les résultats obtenus d'une enquête formelle en milieu réel, ainsi que des évaluations rurales rapides conduites au niveau d'une région sujette à la sécheresse en Inde centrale ont confirmé: 1) que les paysans reconnaissent bien les effets de l'exploitation intensive des cultures de rente, telles la canne à sucre ou le coton dans les zones irriguées, en termes de rendements réduits et d'utilisation augmentée d'intrants; 2) que l'adoption des cultures/variétés et les pratiques d'exploitation appropriées sont mises en oeuvre intentionnellement afin de maintenir des niveaux de productivité à long terme pour les systèmes de culture actuels et prévus; 3) que les paysans s'efforcent d'augmenter ou de maintenir la fertilité du sol en introduisant des légumineuses fixatrices de l'azote dans les rotation culturales — le pois d'Angole précoce, dans le cas actuel. L'adoption généralisée du pois d'Angole précoce a permis la rentabilité de la cultivation à court terme — à travers l'exploitation d'une seconde culture dans la saison post-pluviale — et les paysans s'attendent à la productivité durable à la longue grâce à la rotation de cultures pour maintenir la fertilité du sol.

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Introduction

A study was undertaken to determine the extent of adoption and impact in Central India of the short-duration pigeonpea *(Cajanus cajan* (L.) Millsp.) variety, ICPL 87. Developed from International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) derived material, the variety was released in India as Pragati in 1986. The aims of the study were

- to determine the rate and extent of adoption of ICPL 87
- to document farmer preferences and constraints to adoption
- to survey the impact of adoption on efficiency and sustainability.

This paper focuses on efficiency and sustainability, and aims to determine the influence of farmers' concerns regarding sustainable farming on adoption of short-duration pigeonpea (SDP). Using results from a formal on-farm survey and rapid rural appraisals (RRAs) conducted in a drought-prone area in Central India in 1995, the paper illustrates that sustained productivity and efficiency concerns are addressed via appropriate management - in this case, crop rotation with profitable SDP - in order to capture both short- and long-term gains.

Study area

Farm-level surveys covering the pigeonpea-growing districts of Central India were conducted, cutting across the boundaries of two semi-arid tropics (SAT) research domains defined by ICRISAT as Production Systems (PS) 7 and 8. These systems represent

- the tropical, intermediate rainfall, rainy-season sorghum *(Sorghum bicolor* (L.) Moench)/cotton *(Gossypium hirsutum* L.)/pigeonpea cropping system located in India's eastern Deccan Plateau (PS 7)
- the tropical, low rainfall, primarily rainfed, postrainy-season sorghum/ oilseed cropping system located in the western Deccan Plateau (PS 8) (ICRISAT 1995) (Fig. 1).

The region is part of the Vertisol zone of Central India. The soil type ranges from medium black soils in the plains, to brown soils in hill slopes and coarse shallow soils in highlands. The area is classified as a scarcity zone - a drought-prone area, mainly experiencing low to medium rainfall. From Feb to May, the

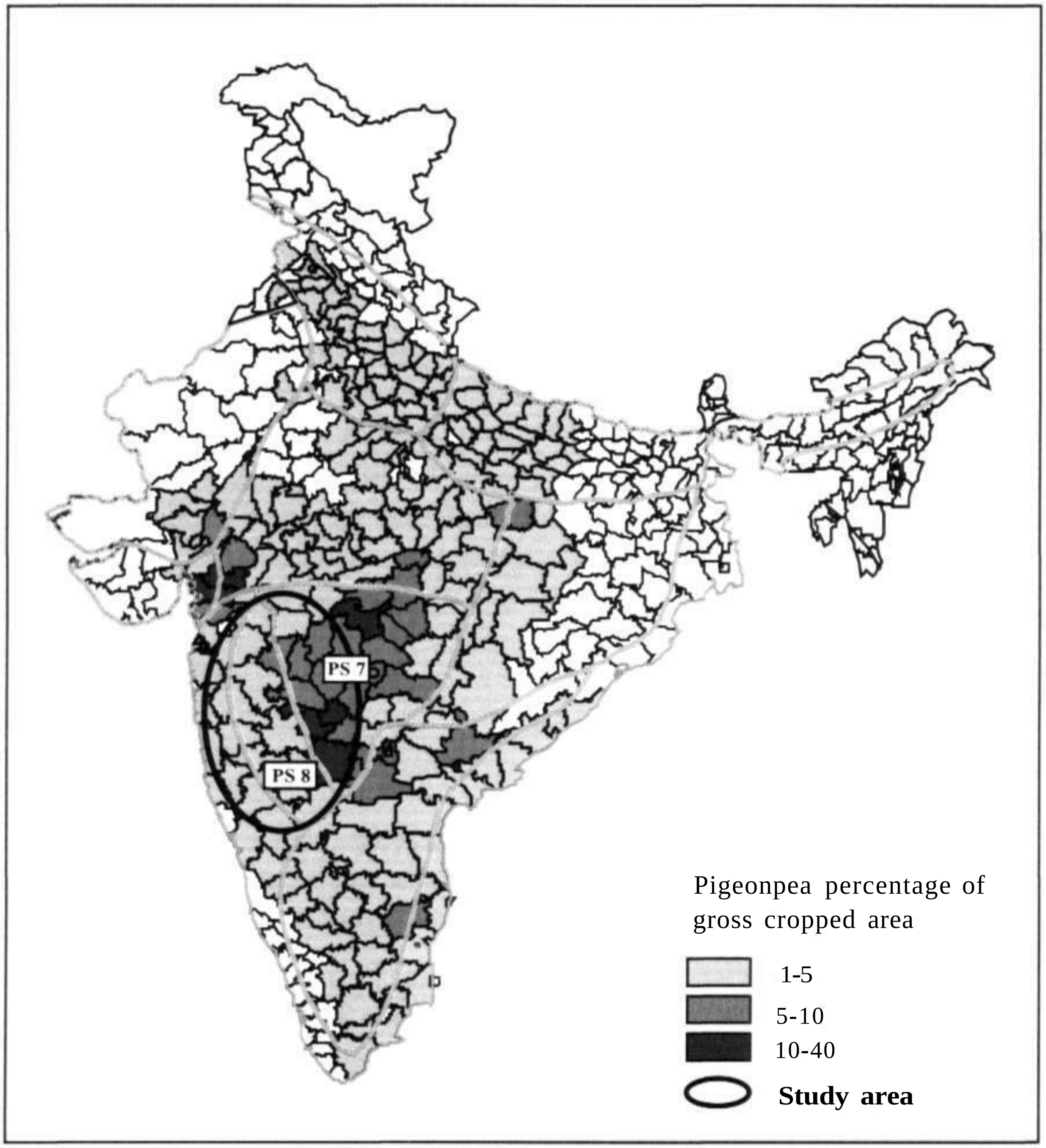


Figure 1. Distribution of pigeonpea in India.

area gets low rainfall of less than 50 mm per month. From Jun to Sep, the area receives medium rainfall of 50-200 mm per month. Zones that lie on the eastern and northern borders of the area receive more than 200 mm per month. From Oct to Jan, the region receives low rainfall of 0-100 mm per month, with most of the region receiving less than 50 mm per month.

The area under pigeonpea in this research domain was estimated at 472 300 ha in 1995 based on data provided by the government of Maharashtra. It covers the districts of Dhule, Jalgaon, Ahmednagar, Nasik, Pune, Aurangabad, Beed, Jalna, Solapur, Satara, and Sangli in the state of Maharashtra, and the adjacent districts of Bidar and Gulbarga in northern Karnataka. The major crops in these districts include pigeonpea, cotton, and hybrid sorghum, apart from pearl millet (*Pennisetum glaucum* (L.) R. Br.), sugarcane (*Saccharum officinarum* L.), horticultural crops, groundnut (*Arachis hypogaea* L.), and vegetables in the rainy season and sorghum, wheat (*Triticum durum* Desf.), and chickpea (*Cicer arietinum* L.) in the postrainy season. The region covers much of the postrainy-season sorghum tract of the SAT of India (PS 8).

The survey covered a representative selection of villages and blocks in eight pigeonpea-growing districts of western Maharashtra and northern Karnataka. The survey was spread over 35 villages from which 277 farmers were randomly selected. The selection of the study site was primarily based on background data obtained from a reconnaissance survey of the pigeonpea-growing tracts in PS 7 and PS 8. Field observations and interviews with regional research and extension staff indicated that the diffusion of ICPL 87 occurred in the regions around western Maharashtra. Data on sales of pigeonpea seeds by the public and private sectors confirmed that adoption was widespread in this region. RRAs complemented the formal on-farm survey, which focused particularly on the efficiency and sustainability gains of ICPL 87 adoption.

ICPL 87 research and development, and extension process

ICPL 87 is an SDP cultivar (120-130 days duration); the variety is determinate, has a short stature, and is semispreading. It was developed through pedigree selection from the cross ICPL 73032 (T 21 X JA 277) made in 1973, soon after ICRISAT was established. In 1980, it was included in the All India Coordinated Pulses Improvement Project. The trials were conducted over five years. The variety was initially targeted for release in northern India for cultivation in rotation with wheat. Around 1983, a decision was taken to test it for possible release in peninsular India. ICPL 87 was first introduced during the mid-1980s in the Vidharbha and Marathwada regions in eastern Maharashtra, i.e., regions that constitute one of the main pigeonpea-growing areas in India. These areas were targeted by the Legumes On-farm Testing and Nursery (LEGOFTEN) technology transfer program - a part of the Government of India's Technology Mission on Pulses implemented in collaboration with ICRISAT Early adoption studies (Kelley et al. 1990) and subsequent reconnaissance surveys revealed that farmers in eastern Maharashtra did not find ICPL 87 suitable for their cropping system. Being a dwarf variety, ICPL 87 was affected by waterlogging in this high-rainfall region and, therefore, farmers found medium-duration varieties to be more suitable for their intercropping systems. The spread of information about SDP to the western part of the state is attributed to further efforts of local research and extension networks from around 1990.

Institutional factors played an important role in enabling the adoption of ICPL 87. Scientists from Mahatma Phule Agricultural University, whose jurisdiction included western Maharashtra, first recommended the variety as suitable for the multiple-cropping systems in the irrigated tracts of the region, particularly in the niches where sugarcane is grown on a large scale. The extension network of the Department of Agriculture in western Maharashtra played a key role in disseminating information on the short-duration variety ICPL 87. Information on dissemination emphasized the following aspects

- improvement of soil fertility in sugarcane-growing areas where farmers can sow SDP in sequence with wheat and chickpea
- suitability of ICPL 87 to the drought-prone areas of western Maharashtra, as it matures early and is more likely to escape terminal drought stress.

As medium and shallow soils in this region tend to have low water-retention capacities, longer-duration varieties are not suitable. In collaboration with the LEGOFTEN technology transfer program that commenced in the late 1980s, the Department of Agriculture introduced SDP materials in their on-farm trials and demonstrations, and catalyzed the production and multiplication of breeder and foundation seed on a large scale. At about the same time, a government extension program called the National Pulses Development Program (NPDP) was activated to provide funds for subsidies, on-farm (mini-kit) trials and demonstrations, and extension support with specific focus on selected varieties that included ICPL 87. The extension program was said to be very active in this region compared to other regions of the state.

Farmers learned and implemented appropriate management practices for sustainable farming, with farmers' organizations facilitating group decisions regarding options based on both traditional practices and improved technology packages. Cooperative organizations, especially sugarcane cooperatives, also played a catalytic role in the early diffusion of the variety by producing seed (in collaboration with the Maharashtra State Seeds Corporation) during the initial period, and by spreading awareness regarding the sustainability of SDP in sugarcane-based cropping systems and its fertility-enhancing benefits to intensively cultivated fields.

Results and discussion

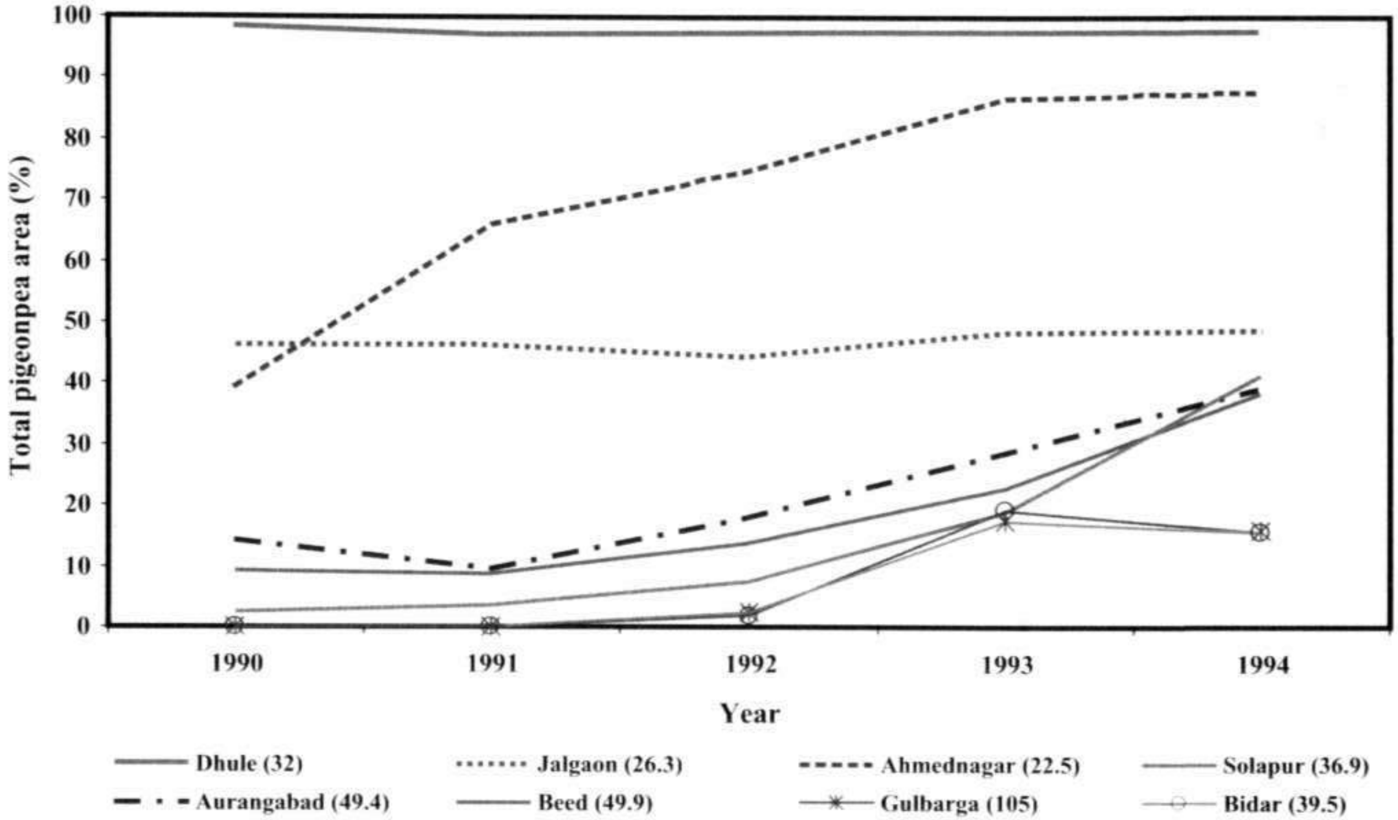
Adoption and diffusion

Gains from SDP research ultimately reach the beneficiaries only when the improved variety is adopted by farmers. This condition necessitates the consideration of the rate of technology adoption and the factors influencing or constraining it (Bantilan and Johansen 1994). Data obtained from on-farm surveys showed that large-scale adoption of ICPL 87 occurred especially in the northern districts of Dhule (98%), Ahmednagar (89%), and Jalgaon (49%) (Fig. 2). Farmers in these three districts are classified as early adopters: they took up ICPL 87 soon after its introduction in the region in 1987. The main reasons cited for adoption are

- short duration
- high yield
- improved soil fertility
- high market price.

Farmers in some villages indicated that pigeonpea is grown mainly to improve soil fertility. Moreover, the relatively short-growing period of ICPL 87 fits exactly into farmers' desired cropping patterns and allows them to adopt the variety in order to sustain and improve the long-term productivity of their soils. It may be mentioned here that ICPL 87 is the only SDP variety adopted in the region.

Secondary district-level statistics indicate that the area under pigeonpea in Ahmednagar has doubled from 11 387 ha in 1985 to 23 309 ha in 1992, and



Note: Gulbarga and Bidar are in Karnataka.
Figures in parentheses refer to total pigeonpea area in '000 ha.

Figure 2. Adoption of ICPL 87 in districts of western Maharashtra and nothern Karnataka, 1990-94.

from 22011 to 44839 ha during the same period in Solapur. While the area under pigeonpea has been increasing across the whole of Maharashtra, the western region achieved the highest growth rate (Fig. 3a).

This increase is mainly due to the adoption of ICPL 87 (Fig. 3b). Farm-level data also confirms that the area under pigeonpea has increased by as much as 51% in many parts of western Maharashtra, especially in the northern blocks. Seed sector data supported by information obtained from reconnaissance surveys also confirmed that large-scale adoption of ICPL 87 has occurred in PS 8 and adjoining areas in PS 7. The neighboring districts of northern Karnataka maintained stable areas of pigeonpea.

A substantial rise in the level of adoption during the period 1988 to 1994 was measured: adoption rates (in terms of percentage of the total area under pigeonpea) increased in western Maharashtra from 3% in 1988 to 35% in 1990, and to 57% in 1994. In northern Karnataka, it rose from 0 to 16% over the seven-year period. In terms of the number of farmers, the rate of adoption grew from 3 to 71% in western Maharashtra, and from 0 to 25% in northern Karnataka.

Varying adoption levels were observed across the districts and blocks (Bantilan and Parthasarathy 1995). Figures 4a and 4b depict the extent of diffusion in eight districts during the period 1990 to 1994. Out of a total of 17 blocks covered in the survey, 6 blocks had at least 90% of their pigeonpea area covered with ICPL 87, while 3 blocks registered an adoption rate between 42 and 65%. ICPL 87 has so dominated the pigeonpea area in this region that farmers in 10 of the 35 villages studied reported that there was practically no other pigeonpea variety grown in their villages except ICPL 87. In these 10 villages, the estimated adoption level ranged from 91 to 100%.

Heterogeneity of soil type, rainfall pattern, and irrigation account for these variations. As mentioned earlier, PS 8 is mainly characterized by marginal soils with low water-retention capacities and early withdrawal of the monsoon. Under these circumstances, SDP is more suitable since it escapes terminal drought stress. Furthermore, farmers in different environments manage their farms according to the occurrence of disease, e.g., fusarium wilt *(Fusarium udum* Butler) and phytophthora blight *(Phytophthora drechleri* Tucker f. sp. *cajani).* Low adoption levels were observed, for example, in villages located in the PS 7 sections of Jalgaon district, which are characterized by more assured rainfall levels. Farmers of Bhusaval block in this district find

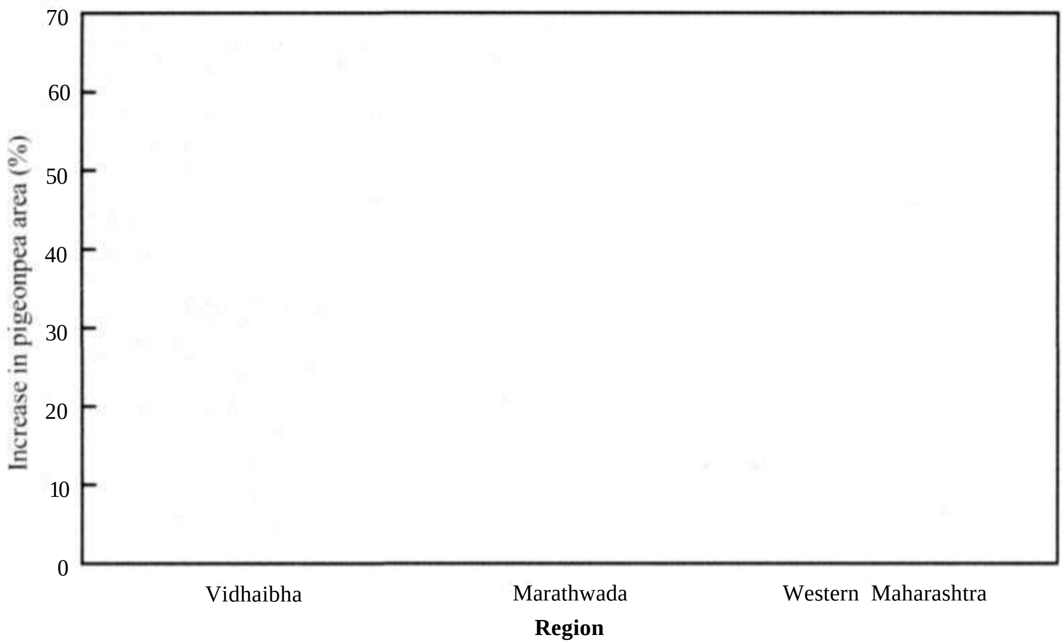


Figure 3a. Increase in pigeonpea are in the regions of Maharashtra, 1987-1994.

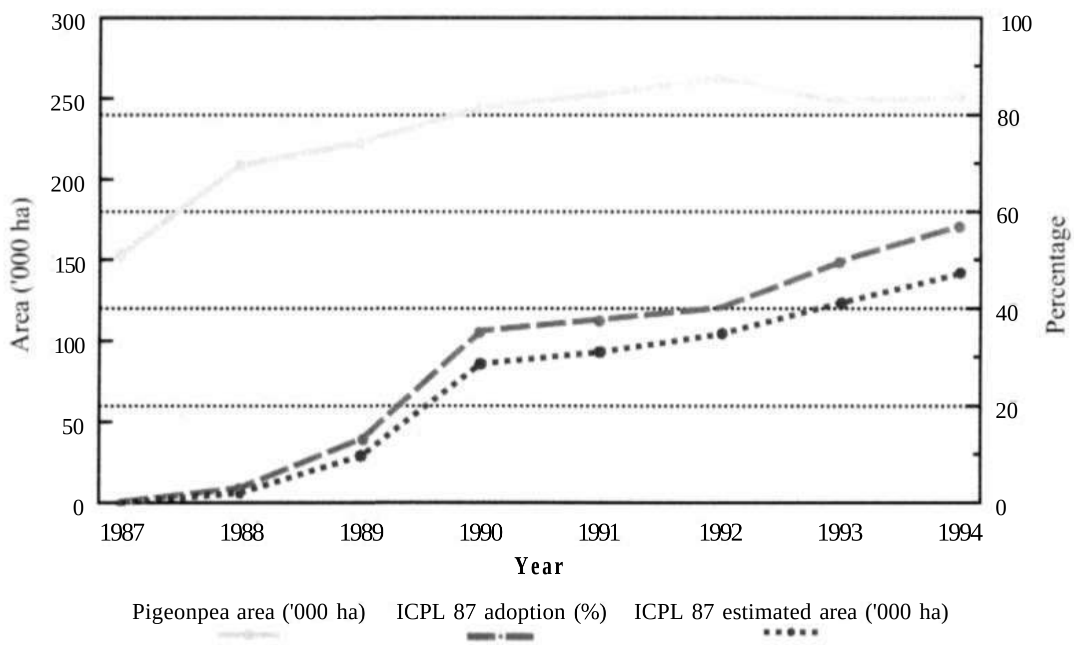


Figure 3b. Pigeonpea area, percentage of adoption and estimated area under ICPL 87 in western Maharashtra.

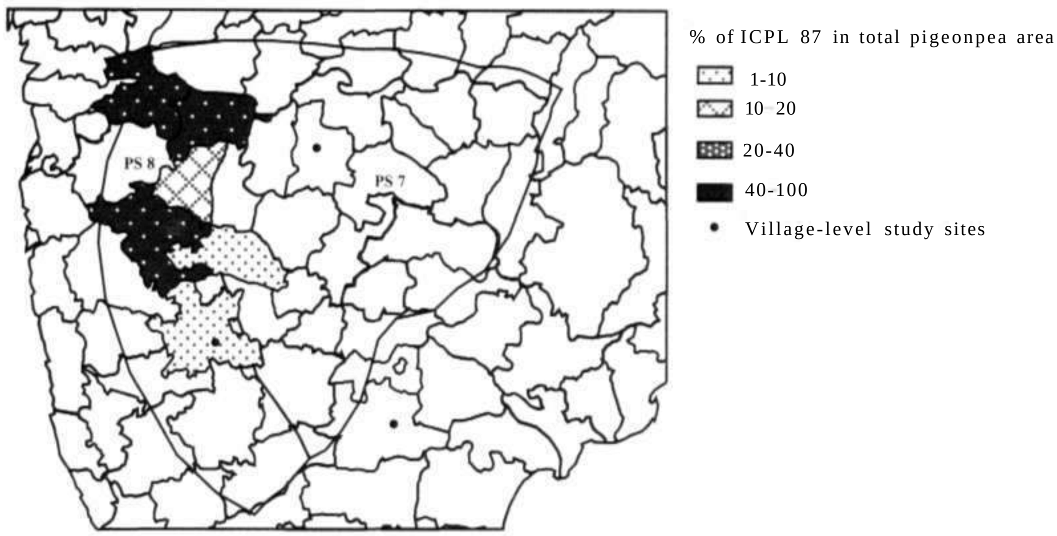


Figure 4a. Adoption of ICPL 87 in Maharashtra and Karnataka, 1990.

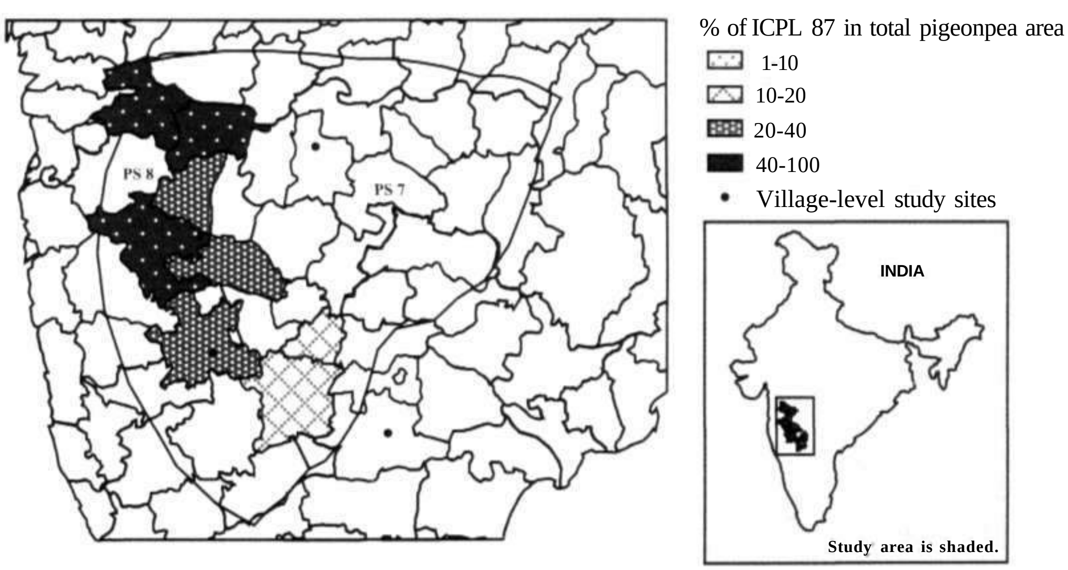


Figure 4h. Adoption of ICPL 87 in Maharashtra and Karnataka, 1994.

medium-duration cultivars more appropriate in deep black soils with waterlogging problems, and where phytophthora blight is endemic. Low adoption rates in Aurangabad, Beed, and Solapur blocks in the same belt can be attributed to serious wilt incidence. Farmers in Akkalkot block of Solapur sought medium-duration, wilt-resistant varieties suitable for intercropping.[1]

The extent of diffusion is also influenced by infrastructural support, e.g., access to seed suppliers and markets. The relatively high rates of adoption in the northern districts (Dhule, Ahmednagar, and Jalgaon) are chiefly due to easy access to the urban markets of Bombay, Pune, and the southern districts of Gujarat, where there is a high demand for pigeonpea grain and green pods. Extension via government support programs also significantly accounts for the variation in adoption. Villages where adoption has increased since 1994 (e.g., Chappalgaon in Solapur and Mandekhel in Beed) have been influenced by programs such as NPDP.

Pigeonpea was a minor crop in this region until the release of ICPL 87. Initially, up to 85% of other pigeonpea varieties were replaced by adopters. Once the initial adoption took place, farmers increased the area under pigeonpea mainly by replacing other crops such as sorghum or pearl millet (21%), or by bringing fallow land under cultivation (65%). Analysis of data from 1990 to 1994 shows that the increase in area under pigeonpea has occurred mainly due to increased adoption (Figure 3b). Areas under other medium-duration varieties over the same period have either remained the same or increased slightly. This also indicates that the adoption of ICPL 87 has largely resulted in the replacement of other crops and has brought fallow land under cultivation. Thus, the initial shift was from medium-duration pigeonpea to SDP. However, with increased awareness of the role of SDP in sustaining the productivity of the system on a long-term basis, farmers shifted from other short-duration crops to SDP.

Impact of adoption

Economic benefits. While the choice of ICPL 87 has been motivated by the ability of the cultivar to fit into desired cropping systems and the need to sustain productivity over the long term, the crop's profitability due to high market prices and higher yields has played a significant role in rapid large-scale adoption.

1. ICRISAT's wilt-resistant cultivar ICP 8863 was targeted at these areas and has been adopted on a large scale in northern Karnataka, which borders this region (Bantilan and Joshi 1996).

Integration of ICPL 87 into double cropping systems was possible due to its early maturity: it enabled farmers to grow postrainy-season crops like sorghum, chickpea, and wheat, which constitute the staple food of the population in this region. Forty-six percent of the adopters sowed a postrainy-season crop in the pigeonpea plots, as opposed to only 9% of the nonadopters. The ability of the crop to fit into the cropping system was, therefore, a major factor in its adoption.

A comparative cost-benefit analysis with the previous best available variety, the medium-duration BDN 2, confirmed higher net benefits from adoption of ICPL 87. Results indicated that the net farm income was higher (30%) for ICPL 87 (Table 1); the grain yield advantage was 93%, and the unit cost reduction around 12% (Rs 1296 t^{-1})[2]. The resultant increase in net income obtained by farmers has been crucial for adoption. The survey clearly indicated that, despite the increased cost for irrigation and fertilizer/farmyard manure (FYM), the adoption of ICPL 87 has had a positive impact on farmers in terms of increased profits at the farm/ household level.

Intensive cultivation of ICPL 87 as a sole crop, coupled with its emergence as a cash crop, especially in small farmholdings, seems to have resulted in farmers bestowing more care on the crop. Labor use actually increased with adoption. In general, men specialize in land preparation and interculture, while female labor is more specialized in weeding, harvesting, and threshing operations. Comparative analysis of ICPL 87 versus BDN 2 showed higher male labor use for almost all operations for ICPL 87. Female labor use was also relatively higher for all operations, except pesticide spraying and threshing. Adopters also incurred comparatively higher costs for irrigation, fertilizer, and FYM. Thus, the higher net benefits for farmers seem to accrue both from ICRISAT's breeding efforts, and adaptive research on crop and resource management in

Table 1. Comparative impact of ICPL 87 and BDN 2 in Maharashtra.

Variety	ICPL 87	BDN 2
Grain yield (t ha^{-1})	1.181	0.611
Unit cost (Rs t^{-1})[1]	9146	10 442
Net farm income (Rs ha^{-1})	5247	4012
Unit cost reduction (Rs t^{-1})	1296	

1. Indian rupees 36 = US$ 1.
Source: Pigeonpea Research Evaluation and Impact Assessment (REIA) survey, 1995.

2. Indian rupees 36 = US$ 1.

collaboration with NARS. SDP was almost like a new crop in the region in terms of crop management.

The benefit springing from the early maturity of the crop and its ability to fit into farmers' desired cropping systems is represented by the additional income from the pigeonpea crop, which is added to farmers' revenues gained from the previous cropping system. Analysis of the cropping system (Fig. 5) shows that pigeonpea has become a major rainy-season crop. Pigeonpea is grown alone or in rotation with wheat, chickpea, or sorghum, and is alternated with other cash crops - sugarcane, cotton, groundnut, and horticultural crops [banana *(Musa sapientum* L.), grapes *(Vitis* spp), and pomegranate *(Punica granatum* L.)] and vegetables - every year in the same plot. That the ability of the crop to fit into the cropping system was a major factor in its adoption is revealed by farmers' responses to the formal questionnaire, wherein the respondents attached the maximum importance to the early maturity characteristic of the variety. As many as 26% of those who were asked the reason for the fluctuation in the area under pigeonpea responded that this was explained by their practice of crop rotation. During RRAs, farmers in most villages expressed a preference for crops that have a duration of less than 4 months. Several reasons were cited, namely

- with increasing fragmentation of landholdings, farmers wish to increase the productivity of their land and produce more crops
- farmers wish to maintain crop diversity both as a risk-averting measure and as a way of avoiding intensive cultivation of the same crop in continuous sequences
- crop diversification with slightly different maturities also enables farmers to avoid labor problems during peak-harvesting periods. ICPL 87, by maturing a few weeks after other short-duration crops such as hybrid sorghum, pearl millet, and soybean *(Glycine max* (L.) Merr.), escapes the peak labor demand period when labor is both scarce and, therefore, costly.

The overall impact of SDP cultivation in terms of increased labor demand seems to be favorable. Agricultural laborers were able to obtain work during the lean season, and farmers were able to harvest their pigeonpea crop at a time when labor was available at a normal price.

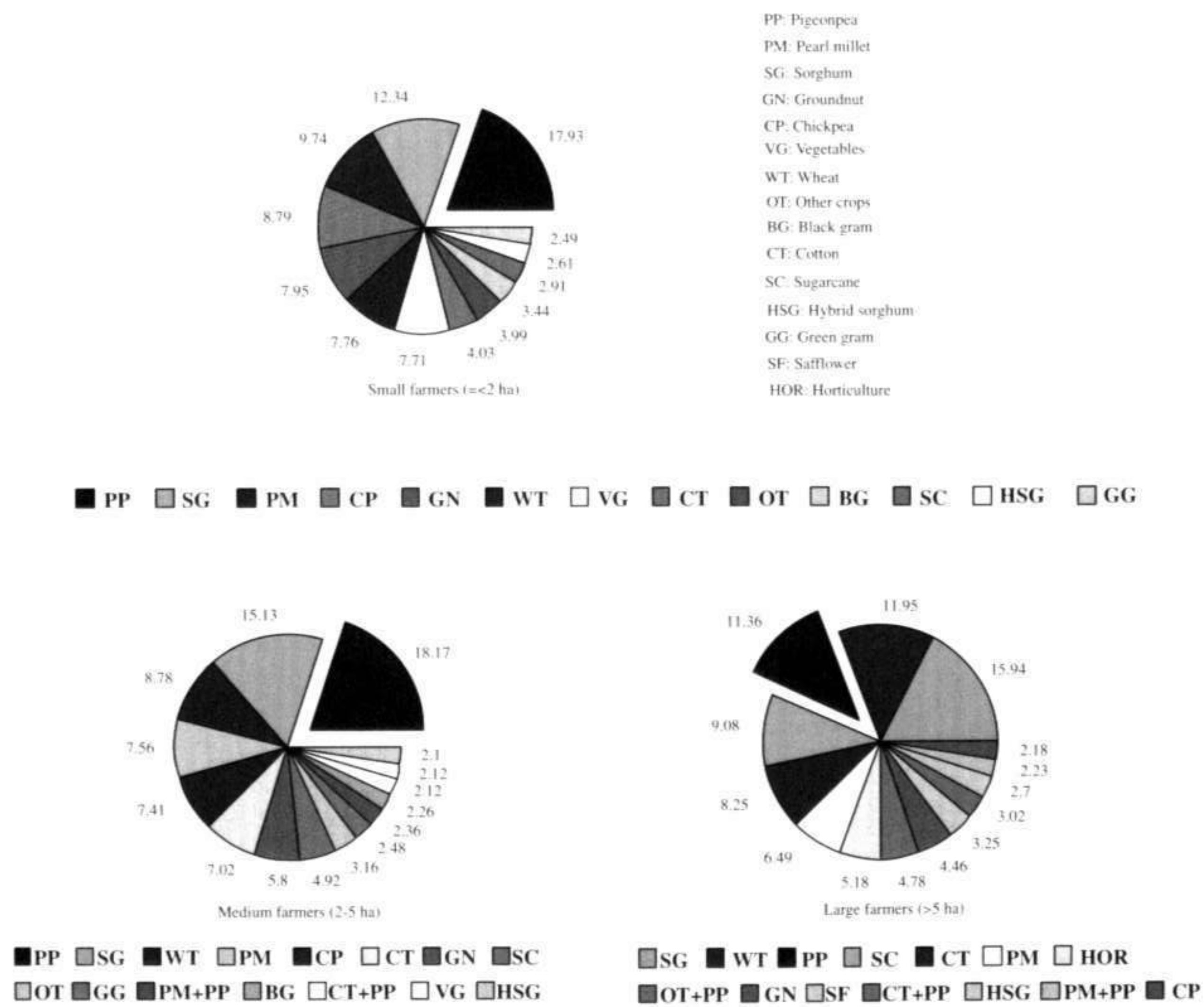


Figure 5. Cropping pattern of small, medium, and large farmers in Maharashtra, 1994.

Table *2.* Total net benefits from different crop rotations.

Crops	Benefits (Rs ha^{-1})[1]
Pigeonpea—onion	2616
Pigeonpea—wheat[2]	7010
Pigeonpea—wheat[2]	6312
Pigeonpea—rabi	4267
Soybean—wheat	9728
Hybrid sorghum—wheat	2540
Pearl millet—wheat	686

1. Indian rupees 36 = US$ 1.
2. Based on two different pigeonpea—wheat samples.

Source: Pigeonpea Rapid Rural Appraisals, Manjoor village, Ahmednagar, Maharashtra, 1996.

Farmers had few viable options other than ICPL 87 to use as a rotation crop that fit the short window between seasons. In the past they grew other short-duration crops such as hybrid sorghum, sunflower *(Helianthus annuus* L.), and pearl millet in the rainy season. However, these crops are significantly less remunerative due to their low prices. Farmers who continue to cultivate these crops do so for home consumption. As the price of pigeonpea has increased in recent years, profitability has become a key factor in replacing sorghum or pearl millet with ICPL 87. The importance of price, both for the adoption of ICPL 87 and the increase in the area under pigeonpea, is reflected in the price range of pigeonpea (i.e., Rs 9-13 kg^{-1} in 1995) compared with the price of pearl millet and sorghum (Rs 3-5 kg^{-1}).

Farmers in some villages also noted that these alternative short-duration crops (i.e., hybrid sorghum and sunflower) deplete soil fertility. Table 2 shows the higher net benefits obtained by pigeonpea-based crop rotations as compared to pearl millet- and sorghum-based rotations.

Analysis of the cropping pattern by the landholding class (Fig. 5) shows that pigeonpea has the largest share in the gross cropped area among small and medium farmholdings. Small farmers, who constituted 22% of the sample and who owned less than 2 ha, adopted ICPL 87 on a large scale (70%). This group traditionally grew more wheat and subsistence crops such as sorghum, pearl millet, and chickpea. With the availability of ICPL 87, these farmers have gained substantially. Since pigeonpea, in comparison to other cash crops, requires less inputs in marginal lands, it has become a major cash crop for these farmers. The higher net income obtained from pigeonpea is, thus, of great significance, and has played a major role in its adoption.

Sustainability dimension. ICPL 87 is advantageous both to large and small farmers primarily because

- it allows a second crop in the postrainy season
- it helps maintain long-term productivity through enhanced soil fertility.

This section addresses the second advantage. The benefits of growing pigeonpea in rotation with other crops (namely, nitrogen fixation, phosphorus nutrition, and deep-rooting ability) are widely known (Hoshikawa 1991).

Studies have shown that the root nodulation of pigeonpea fixes atmospheric nitrogen at a rate that reduces the inorganic nitrogen fertilizer requirements for subsequent crops. Specifically, experimental results show substantial residual effects of pigeonpea on succeeding crops (Table 3; Kumar Rao 1990). Trends indicate that the rotation of medium-duration and high-nodulating pigeonpea genotypes provides larger beneficial effects on succeeding crops than short-duration types. Field experiments further suggest that while biological nitrogen fixation of SDP may probably be adequate to meet the nitrogen (N) requirements of the crop grown in Alfisols, Inceptisols, and Entisols, it is not adequate in Vertisols (Kumar Rao et al. 1995). The substantial residual effects of another SDP cultivar, ICPL 151, suggest a rapid breakdown and release of N from decomposing SDP material (Johansen unpublished, cited in Kumar Rao et al. 1995). The increased beneficial effects of pigeonpea to subsequent crops with higher plant density is also noted (Whiteman and Norton 1980). Since SDP is usually sown as a sole crop, plant densities are higher than for medium and long-duration varieties. Ramakrishna et al. (1994) summarize on-station trial results showing pigeonpea to be worth between an equivalent of 30-70 kg ha^{-1} of N. Apart from transferring fixed N_2 to the succeeding crop, pigeonpea cultivation also substantially increases the total soil N in pigeonpea-based cropping systems (Wani et al. 1994).

Pigeonpea can also be used as a green manure crop where the biomass in the form of pigeonpea residues is returned to the soil as manure or compost (Hoshikawa 1991). Factors other than N also contribute to the beneficial effects of pigeonpea on soil fertility (Arihara et al. 1991). These include utilization of iron-bound phosphorus (P): pigeonpea converts soil P into an available form due to its unique root exudates and increases the available P pool (Ae et al. 1991). It is noted that next to N, P is usually the most deficient nutrient in the soils of the SAT (Hoshikawa 1991).

The deep-rooting ability of pigeonpea permits greater extraction of soil water and nutrients at depth. It also increases the water infiltration rate for

Table 3. Residual effects of pigeonpea (PP).

Pigeonpea crop duration	Rotation	Variety	Residual benefits (in equivalent kg N ha^{-1}) to following crop	Yield/biomass/nitrogen status gain
Medium	Sole PP—maize		40[1]	57% increase in grain yield; 32% increase in total biomass compared to fallow—maize rotation
	PP—sorghum	ICIP 1.6	30[2]	
	PP/maize—sugarcane			43% increase in sugarcane yield compared to sole maize yield; improved soil nitrogen status[3]
	Sole PP—maize			Substantial nitrogen economy in maize[4]
	PP/grain legumes—maize			Substantial nitrogen economy in maize[4]
Short	PP—wheat	UPAS 120	negligible[5]	
	PP—wheat	ICPL 151	40[6]	
	PP—sorghum	ICPL 87	5[7]	

Sources:
1. Kumar Rao et al. 1983.
2. Kumar Rao et al. unpublished, cited in Kumar Rao 1990.
3. Yadav 1981.
4. Rathnakumar 1983, cited Ahlawat et al. 1986.
5. Singh and Verma 1985.
6. Johansen unpublished, cited in Kumar Rao et al. 1995; ICRISAT 1989.
7. Kumar Rao et al. unpublished, cited in Kumar Rao 1990.

subsequent crops, helps in recycling nutrients, and improves soil structure.

Pigeonpea also contributes to increased soil-microbial activity (Wani et al. 1994), and breaks pest and disease cycles (Hoshikawa 1991). SDP cultivars, such as ICPL 87, also have these properties (Arihara et al. 1991), but they have shallower rooting habits than medium-duration varieties (Chauhan 1993).

The formal surveys and RRAs strongly confirm that sustained productivity of the land is an important factor in influencing farmers to adopt ICPL 87 and modify their crop rotations. A majority of the farmers from 12 villages where

RRAs were conducted expressed awareness of the following aspects

- the causes of declining fertility
- the consequences of intensive cultivation
- the capacity of legume crops to improve soil quality.

In six of the villages, farmers showed awareness of soil-degradation problems such as soil erosion, waterlogging, and soil salinity.

ICPL 87 was also frequently mentioned as a boundary crop to prevent soil erosion. Farmers' responses to questions regarding their reasons for adopting ICPL 87 suggest the importance of the sustainability dimension. This is highlighted by the summary of responses to a multiple-response question on desirable traits (Table 4, relative ranks are given in column 4). At least 90% of the respondents cited "short duration" and "increased grain yield" as desirable traits influencing adoption. Around 49% of the respondents specifically mentioned "improved soil fertility" as a reason for adoption. Importance was also given to "market price" (45%).

The importance of ensuring soil fertility in intensive cropping systems is evident from farmers' responses obtained via interviews. Farmers involved in intensive cultivation of sugarcane, cotton, sunflower, and hybrid sorghum perceived that soil nutrients were being depleted. They observed declining yields in spite of using more inputs. Management practices were reported to be consciously adopted in order to maintain productivity levels in the context of existing and desired cropping systems. Farmers practiced rotation of SDP with sugarcane and other crops. In some villages, farmers rotated pigeonpea in all their plots in turn each year - a practice known locally as bher phalat. Farmers were also found using pigeonpea biomass/by-products as manure/compost. Among the sample farmers, 21% reported using pigeonpea residues as manure or compost. Farmers either allowed the residues to decompose or burnt the stalks after harvest in the field. Farmers maintained that pigeonpea not only fixed atmospheric nitrogen, thereby reducing fertilizer requirements for the subsequent crop, but also improved the soil structure, enabling easier land preparation and better germination. Results of a case study undertaken in Manjoor village of Ahmednagar district revealed that on an average farmers saved as much as Rs 190 ha^{-1} on FYM and Rs 1149 ha^{-1} on fertilizers for the subsequent wheat crop by adopting pigeonpea-based cropping systems as compared to pearl millet or sorghum-based cropping systems (Table 5). Since a number of crops are sown in rotation with SDP, the data on fertilizer costs suggests that these cost reductions are likely to be higher or lower than the figures given, depending on the fertilizer requirements of the subsequent crop.

Table 4. Farmers' feedback regarding desirable traits of ICPL 87.

Trait	Frequency[1]	Percent	Rank[2]
Short duration	133	93	1.00
Increased grain yield	128	90	.96
Improved soil fertility	70	49	.36
High market price	65	45	.36
Better taste	19	13	.09
Disease resistance	18	13	.10
Less cooking time	15	11	.06
Insect resistance	5	3	.03
Color	4	3	.01
Drought tolerance	4	3	.03
Good fodder quality	2	1	.01
Bigger grain size	1	1	.01
Others	26	18	

1. Multiple responses were provided by a random sample of 143 farmers.
2. Relative importance of traits is weighted by ranks (r) provided by respondents.
Source: Pigeonpea Research Evaluation and Impact Assessment (REIA) survey, 1995.

The pattern of land ownership among the farmers studied may also explain the great degree of concern among them for the future productivity of their land. Almost all farmers (97%) owned the land they cultivated. Half of those who did not own their land were recorded as nonadopters. It is also noted that 70% of the land area under ICPL 87 is marginal or inferior (Table 6). As land is an important resource for these farmers, they have a strong incentive to seek options to ensure longer-term productivity. Furthermore, as stated earlier, SDP is more suitable for marginal soils in terms of its ability to escape end-of-season drought stress. The increased availability of irrigation in some areas has enabled farmers to obtain higher yields from marginal soils. Concerns regarding sustainability were significant among less well-endowed

Table 5. Relative costs incurred on farmyard manure (FYM) and fertilizers for the postrainy-season crop in pigeonpea and nonpigeonpea rotations.

Crop rotation	Costs incurred on FYM and fertilizer for the wheat crop	
	FYM (Rs ha^{-1})[1]	Fertilizer (Rs ha^{-1})
Pigeonpea—wheat[2]	1651	1829
Pigeonpea—wheat[2]	1778	1587
Pearl millet—wheat	2032	2667
Hybrid sorghum—wheat	1778	3048

1. Indian rupees 36 = US$ 1.
2. Costs for pigeonpea based on two different samples.
Source: Pigeonpea Rapid Rural Appraisals, Manjoor village, Ahmednagar, Maharashtra, 1996.

Table 6. Land quality of pigeonpea plots in western Maharashtra (% of total pigeonpea area).

Quality	All pigeonpea varieties	ICPL 87	Other varieties
Good	33.8	30.5	39.8
Marginal	58.5	64.2	48.2
Inferior	7.7	5.3	12.0
Total	100	100	100

Source: Pigeonpea Research Evaluation and Impact Assessment (REIA) survey, 1995.

farmholdings where previous farming practices were perceived to have led to fertility depletion and rising input costs to maintain yield levels.

Farmers' interest in sustaining long-term productivity is reflected in the changes observed over the years. During RRAs, farmer groups were asked about the major changes in the cropping system in the villages over the past 10 to 15 years. Farmers maintained that the decline in the area under such crops as sugarcane, sunflower, cotton, and hybrid sorghum, which require intensive cultivation and deplete soil fertility, was a major change. The increase in area under short-duration crops, such as pigeonpea and soybean, was the other major change mentioned. In most of the villages, it was observed that these changes coincided with the introduction of pigeonpea, especially SDR

Farmers reiterated during the RRAs that the larger benefits perceived from growing ICPL 87 came from the following sources

- nitrogen-fixation ability of ICPL 87, although relatively lower compared to medium- and long-duration pigeonpea varieties
- higher plant densities of ICPL 87 grown as a sole crop, which yield greater stalk and fallen leaves biomass.

Within the SDP cropping system, the specific practices cited by farmers during the formal and informal surveys that contribute to increased sustainability include

- rotation of all their crops in different plots every year
- cultivation of other legumes, particularly chickpea, groundnut, and minor pulses, which also contribute to enhancing soil fertility
- use of much higher levels of FYM by adopters of ICPL 87.

There are certain important issues that concern the sustainability impact of

SDP cultivation that warrant further analysis. These include

- high rate of adoption of SDF, which could result in the lack of diversity in pigeonpea species and make ICPL 87 more vulnerable to pest attacks
- increased use of pesticides beyond recommended levels, which may detract farmers' attempts to practice sustainable farming.

A follow-up study that addresses these concerns in order to provide a comprehensive account of both the beneficial and the negative effects of SDP adoption would be useful. It would help scientists to develop varieties of SDP that more closely match farmers' needs. Further research in SDP technology that focuses on pest control and resistance to phytophthora blight *and heli coverpa armigera* is advocated.

Conclusion

Feedback obtained from on-farm surveys reveals a strong relationship between technology adoption and farmers' concerns regarding sustainable farming. Within the context of maintaining a desired cropping system, farmers aim to make short-term profits, and also ensure long-term and sustained productivity. The surveys confirm that farmers are forward-looking; they perceive and plan for the long-term productivity of their land, and have consciously adopted SDP to achieve it.

Adoption of ICPL 87 was essentially the introduction of a new crop into regions with traditionally low levels of pigeonpea cultivation. Survey results indicate that the area under pigeonpea increased substantially in western Maharashtra during the period 1987-1995. Analysis of secondary data also indicates that the growth rate of the area under pigeonpea in this region is higher compared to the other pigeonpea-growing districts of Maharashtra. Farmers considered ICPL 87, in rotation with a major cash crop in different plots each year, to be a profitable option in improving soil fertility.

Integration of SDP into the consequent double cropping system has constituted an important change in the last 10 years. ICPL 87 has found its way into fallow lands and is grown in rotation with other crops. It has established a niche in the scarcity zone of Central India's western and eastern Deccan Plateau, where it was found suitable to the regions' agroecological features, resource availability, and existing or desired cropping systems.

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