Rice-Wheat Consortium Technical Bulletin 9

Reintroduction of Extra Short Duration Pigeonpea (ICPL 88039) in Rice-Wheat Systems of the Indo-Gangetic Plains

Rice-Wheat Consortium for the Indo-Gangetic Plains
International Crops Research Institute for the Semi-Arid Tropics

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The initial support from the Asian Development Bank (ADB) and International Fund for Agricultural Development (IFAD) provided the groundwork for establishment of the RWC in 1994 and formalizing the collaborations between the NARS, IARCs and ARIs. The NARS-driven strategic ecoregional research initiatives with financial support from the Government of the Netherlands, Development Fund for International Development (DFID), UK, New Zealand, Australia and the US Agency for International Development (USAID) and the World Bank have grown over the years into a dynamic agenda of resource conservation technologies appropriate to different transects of the Indo-Gangetic Plains. The on-going successes in scaling-up resource conservation technologies for enhancing productivity and sustainability of the rice-wheat systems are beginning to create a revolution and favorably benefit large areas and more numbers of farm families.

The work was supported by the USAID through the Rice–Wheat Consortium for the Indo-Gangetic Plains

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Abstract

Rice–wheat cropping systems (RWCS) are managed on 10 million ha in the Indo Gangetic Plains (IGP) of India. Recent reports, however, indicate that the system is under fatigue and the growth rate of rice and wheat has started declining. Natural resources, particularly soil and water, are threatened because of their over exploitation. Water efficient legumes such as pigeonpea can play an important role in reversing the process of degradation of soil and water resources, and improving the production potential of RWCS.

Among legumes, pigeonpea [*Cajanus cajan* (L.) Millesp] has been an integral part of RWCS and was widely grown in early sixties. However, agricultural polices of the Green Revolution era beginning 1970 focused on increased production through the introduction of input-responsive cultivars of rice and wheat, which not only replaced or marginalized the traditional long and short duration cultivars of pigeonpea but also made them unsuitable even to be used as a break crop in the existing RWCS. It is in this context that ICRISAT developed extra short duration pigeonpea (ESDP) cultivar ICPL 88039. This genotype was evaluated along with traditional cultivars for its suitability as a break crop to restore soil heath, and improve productivity of RWCS.

A large volume of literature is available on studies related to the beneficial effects of legumes on the productivity of rice and wheat. In this bulletin, attempts have been made to briefly describe the process and important findings of reintroducing pigeonpea, particularly ESDP genotype ICPL 88039 in the pigeonpea–wheat rotation by scientists from Indian Council of Agricultural Research (ICAR), Rice–Wheat Consortium (RWC) of the Indo-Gangetic Plains, State Agricultural Universities (SAUs) and International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in partnership with farmers. Efforts were made to identify the constraints and opportunities in growing ICPL 88039 in rotation with wheat for its long term sustainability and resource conservation in RWCS in the IGP. This technical bulletin provides information on the abiotic, biotic and socio-economical constraints that can limit ICPL 88039 production in the RWCS. Color photographs are included to facilitate identification of insect and diseases. A package of practices for ICPL 88039 is also included for use of the farmers, researchers and scientists.

Acknowledgements

The authors are grateful to the management of SAUs, ICAR, CIMMYT, ICRISAT and USAID for funding some of the research and development reported in this bulletin. We acknowledge the contribution and support of ICAR institutions and SAU centers for rice and wheat research and crop diversification in facilitating the multi-location initial evaluation and validation trials with ESDP at farmers' fields. We gratefully acknowledge the contributions of all the farmers who participated and cooperated in conducting on-farm trials. We thank the technical staff of ICAR institutions, RWC, ICRISAT and especially SAUs in the state of Haryana, Uttar Pradesh and Bihar for their support and help in conducting these studies and collecting the relevant data sets. We thank the editor, Ms Sheetal Vyas for making this technical bulletin reader-friendly, and finally Mr D Rangaswamy Reddy from ICRISAT for compiling the technical bulletin and coordinating the production process.

Contents

Foreword

The rice–wheat cropping system (RWCS) is one of the world's largest agricultural production systems, occupying 10 million hectares of cultivated land in the Indo-Gangetic Plains (IGP) of India. It accounts for about one-third of the area grown to both rice and wheat in South Asia and produces staple grain that feeds over 500 million people.

Though the Green Revolution led to impressive gains in rice and wheat production from 1965 to 1985, this was at the cost of grain legumes that have since been relegated to less favorable environments. This situation prevails despite the long-term sustainability of cropping systems where cereals dominate. It has resulted in less availability and the consequent relative price rise of grain legumes, specifically in areas where cereals dominate. It has had an adverse effect on the poor who have limited access to alternative sources of protein, vitamins and minerals that grain legumes can provide.

There are increasing concerns about the sustainability of cereals in a continuous rotation and the fear that future increases in rice and wheat production may not keep pace with demand as the population continues to increase. Rice and wheat growing areas have shrunk in per capita terms from 1200 sq m in 1961 to 700 sq m in 2004. Further intensification is ruled out in villages where the areas under rice and wheat have already doubled or trebled. Therefore, increasing the yield or maintaining current levels of production is the only strategy to cope with growing demand. However, the very high levels of yield growth achieved in North-western IGP during the Green Revolution era cannot be replicated. Rising production costs, water-induced land degradation, gradual loss of soil fertility and the increasing incidence of insect-pests are other limitations to production. Agricultural scientists and economists now fear that food production may fail to increase by 2.5% annually – the rate required to feed growing populations, raise incomes and reduce malnutrition. To meet this challenge, technologies that will enhance productivity, ensure environmental safety and conserve natural resources are urgently needed.

This publication explores the new opportunities of the ICRISAT-bred extra short duration pigeonpea (ESDP) variety ICPL 88039 in the rice–wheat cropping systems of the Indo-Gangetic Plains of India. This is a joint effort by scientists from the Indian Council of Agricultural Research (ICAR), the Rice–Wheat Consortium (RWC) of the IGP, State Agricultural Universities (SAUs) and ICRISAT in partnership with farmers.

The reintroduction of water use-efficient legumes as a break crop in the rice–wheat rotation is an emerging technology. The bulletin elucidates on the process and the important findings of the reintroducing of ICPL 88039 in the pigeonpea–wheat rotation system, with an emphasis on identifying the constraints and opportunities in growing it in rotation with wheat for its long term sustainability and resource conservation. Including ICPL 88039 in the rice–wheat rotation not only acknowledges the role of legumes in ensuring the long term sustainability of cereal-based cropping systems but also enhances the scope of including the essential element of providing nutrition ie, protein, to the millions of vegetarian rural poor in the IGP.

The authors have done a commendable job of compiling information pertaining to ICPL 88039 in a simple yet comprehensive manner. I am sure the bulletin will serve as a useful guide to scientists, researchers, extension specialists and farmers, as it addresses the issue of sustainability of cropping systems in general and rice–wheat cropping systems in particular.

William D Dar
Director General
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Reintroduction of Extra Short Duration Pigeonpea (ICPL 88039) in Rice-Wheat Systems of the Indo-Gangetic Plains

The context

Pigeonpea (*Cajanus cajan)* is one of the most important wet-season grain legume crops in South Asia. The average yield of the crop is around 0.75 t/ha and it occupies the field for 6-9 months. Crop improvement efforts in pigeonpea have been directed both to improve yield of traditional types and to develop new plant types that fit well into new production systems. So far, the emphasis has been on traditional types because most of the area under the crop is planted to them. Traditional cultivars and landraces are photoperiod sensitive and more resilient to adverse conditions. These types are more suitable for subsistence agriculture with low plant density under mixed or intercropping situations. Adoption of short duration pigeonpea (SDP) genotypes developed in the 1960s and 1970s to substitute long duration genotypes has been limited due to their poor ability to fit into rotations with other crops such as wheat (*Triticum aestivum*) (Singh 1996).

Several factors have necessitated the development of extra short duration pigeonpea (ESDP) genotypes that can be grown intensively as a mono-crop. They include: the ongoing intensification of rice and wheat cropping systems (RWCS) in the Indo-Gangetic Plains (IGP), and the need for resource conservation along with a need to focus on crop diversification with legumes to sustain rice and wheat yields and increase productivity (Singh and Dwivedi 2006). While these genotypes have been found useful in terminal drought environments, their usefulness and potential in sequence cropping such as pigeonpea–wheat rotation for which they have been developed has not been fully assessed and realized. For their acceptability in sequence cropping (pigeonpea–wheat), ESDP has to be not only higher yielding than currently used varieties but also need to improve yield of the succeeding wheat or any other crop, in the post-rainy season. Additionally ESDP yield and profitability need to match profitability of rice in markets. Compared with SDP cultivars that have been traditionally used in the pigeonpea–wheat rotation system, there is little information available on the on-farm performance of ESDP genotypes. However, such information is necessary to determine their acceptability to farmers and provide feedback on future research. It is in this context that the Rice–Wheat Consortium (RWC) for the Indo-Gangetic Plains (IGP) and International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in collaboration with the Indian Council of Agricultural Research (ICAR) institutes, State Agricultural Universities (SAUs) and non-governmental organizations (NGOs) conducted a series of on-farm farmers' participatory trials (FPT) on ESDP genotype ICPL 88039 in RWCS of IGP in the past decade.

Objectives

1. To reintroduce ESDP genotype ICPL 88039 for crop diversification;

2. To identify constraints and opportunities in ICPL 88039 adoption;
3. To enhance ICPL 88039 adoption and expansion to large numbers of farmers;
4. To elicit farmers' perceptions about ICPL 88039.

The Pigeonpea–wheat rotation system

Pigeonpea is a rainy season crop, which requires little input of fertilizer, and thrives well even under limited rainfall situations due to its deep root system. It can provide considerable residual benefit for succeeding crops such as wheat (Johansen et al. 1990). The crop has been traditionally grown as an intercrop or mixed crop with a number of cereals such as sorghum (*Sorghum bicolor* (L.) Moench.), pearl millet (*Pennisetum glaucum* L.) and maize (*Zea mays* L.) when sown at the beginning of the rainy season (Figure 1 and Figure 2). The primary reasons for pigeonpea being considered a remunerative break (diversification) crop for rice–wheat systems are: remunerative price for its grain, less water requirement for growth, fuel-wood yield and its ability to improve soil fertility. A number of SDP cultivars that can fit in crop rotation with wheat were developed under the aegis of the All India Coordinated Pulse Improvement Project in the 1960s, and later at ICRISAT from 1972 (Dahiya et al. 2001). The SDP-based system, however, was not adopted as anticipated and the area stagnated. The available SDP

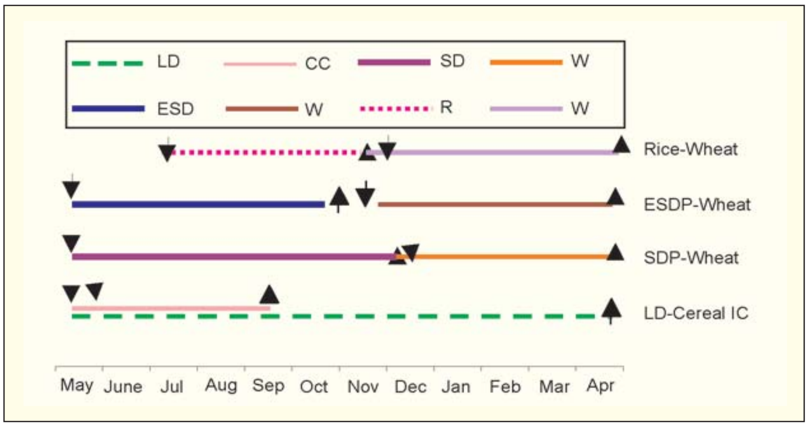

Figure 1. Pigeonpea, rice and wheat-based cropping systems with approximate swing (⌒) and harvesting times (-) of sequences; LD = long duration pigeonpea, Cereal IC = cereal inter-crop; SD = short duration pigeonpea; ESDP = extra short duration pigeonpea; and R = rice, W = wheat, CC = cereal crop.

Figure 2. Pigeonpea variety ICPL 88039 with maize in the Indo-Gangetic Plains of eastern India.

varieties were susceptible to pests, had small seed size, low and unstable yields, and force-delayed wheat sowing. Their tall plant height made management of pests difficult. This necessitated the development of ESDP variety with bold seed size, and reduced susceptibility to insect pests and diseases for use in pigeonpea–wheat rotation (Figure 3).

Figure 3. Traveling seminar participants discussing benefits of planting ICPL 88039 on raised beds with Mr. Akhtar Khan in Village Kaloogarhi, Ghaziabad, UP.

Genesis of ESDP variety ICPL 88039

As a result of natural and deliberate selection of pigeonpea for different production systems, a wide range of maturity types exist. Actual phenological expression at a particular location is controlled by photoperiod and temperature regimes, as pigeonpea is a quantitative short-day plant (Byth et al. 1981). Based on the phenology data of two sites in India, ICRISAT Center-Patancheru (17^0 N) and Hisar (29^0 N), Gupta et al. (1989) classified short duration pigeonpea into two broad groups: ESDP and SDP.

The ESDP variety ICPL 88039 is one of the earliest maturing varieties bred at ICRISAT. It was developed using the pedigree selection method and was identified for yield evaluation in 1988. In the Deccan Plateau, its plant height is about 1.5 m, it flowers in 45-55 days and matures in about 90 to 100 days. It has attractive yellow flowers, brown seeds with 100 seeds weighing about 10 grams. In North India, the ESDP variety ICPL 88039 takes about 120-150 days to mature compared to 180-270 days taken by traditional medium- and long-duration types. It matures 3-4 weeks earlier than SDP varieties in the northern latitudes. The sub-tropical environment in the rainy season of IGP aids better growth and dry matter production of ESDP than the tropics.

Tests with ESDP variety ICPL 88039

How ICPL 88039 compares with SDP varieties

A series of on-farm trials were conducted between 1995 and 2000 in the following locations in North India: Sonepat district (28^0 N), Haryana; Ghaziabad district (28^0 N), Uttar Pradesh; and Ludhiana district (30^0 N), Punjab. The objective was to determine the suitability of ESDP genotypes (ICPL 88039 and ICPL 85010) vis-a-vis SDP cultivars (Manak, UPAS 120 and T 21) in rotation with wheat, and also to identify constraints to their production. As part of the farmers' participatory evaluation, ESDP and SDP pigeonpea cultivars were provided to farmers to identify acceptable genotypes through field evaluation. This exercise gave first hand information on the consequences of including these cultivars into the actual rice–wheat production system, farmers' opinions and feedback, and any likely additional benefits. The other advantage of on-farm testing was the direct exposure of ESDP and its production technology to the existing social and natural environment.

The soil in all the on-farm trial sites was sandy loam with about 100 mm plant-available water per meter soil depth. In general, soils were caleareous with pH of 8.2-8.3, non-saline and low in available N (79-84 mg/kg). Farmers were provided with seeds of indeterminate ESDP genotype ICPL 88039, together with some consultative inputs from scientists. Farmers were responsible for identifying land, arranging seeds of local genotypes (mostly UPAS-120) for comparison with ESDP, choosing the sowing date and further management of the on-farm trials. The farmers further sub-divided their 0.4-0.6 ha experimental field into two equal parts and the supplied ESDP genotype ICPL 88039 was assigned randomly to the plot.

Basal doses of approximately 18 kg N and 20 kg P/ha were applied to the fields before sowing. Fields were prepared before sowing with irrigation to ensure good germination and crop establishment; this is common practice for pigeonpea cultivation in the region as irrigation facilities are widely available. Sowing dates of the various on-farm trials ranged from 1 May to 20 June across the different years. Seeds were sown in rows 40 cm apart, giving a final stand of 10-12 plants per m^2.

After about 96 on-farm trials, ESDP genotype ICPL 88039 emerged the highest yielder over other SDP genotypes. Its yields were 5-16% more than the test SDP control cultivar at different locations (Table 1). Its seed weight was always found to be between 9-10 g/100 seeds. The ESDP variety ICPL 88039 was also found to be relatively tolerant to pod borer (*Helicoverpa armigera*) damage (Dahiya et al. 2001, Dahiya et al. 2002).

Table 1. Comparison of grain yield (t/ha) of ESDP and SDP cultivars grown at Sonepat (Haryana), Ghaziabad (Uttar Pradesh) and Ludhiana (Punjab), India[a], 1995-2000.

Cultivar	No. of trials	Yield (t/ha)			
		Sonepat	Ghaziabad	Ludhiana	Mean
ESDP					
ICPL 88039	96	1.48	1.54	1.69	1.57
ICPL 85010	52	1.41	1.22	1.58	1.40
AL 201	1	-[b]	-	1.60	1.60
SDP					
Manak	69	1.28	1.08	-	1.18
UPAS-120	9	-	1.05	-	1.05
T-21	1	-	-	1.66	1.66

[a]Based on Dahiya et al. 2002; [b] Not included in on-farm trials.

Performance of wheat following ICPL 88039

The performance of ESDP varieties (ICPL 88039 and ICPL 85010), and traditional SDP varieties (Manak, T-21, AL 201) were also judged by the performance of wheat as following crop. The trials were conducted on-farm in 1996-97 and 1997-98 in Sonepat, and in Ludhiana. At Sonepat, ESDP variety ICPL 88039 matured three weeks earlier, yet gave 12% higher yield (1.57 t/ha) and showed less susceptibility to pod borer (*H. armigera*) damage than the other short duration variety Manak (Table 2). At Ludhiana, ESDP varieties ICPL 88039 and ICPL 85010 and SDP AL 201 gave similar grain yields in comparison to the variety T21. However ESDPs matured three to four weeks earlier than SDP (Table 3) At both these locations, a wheat crop (*Triticum aestivum* cv. HD 2329) followed pigeonpea, and yields of wheat following ESDP were upto 0.75 t/ha above average yields at Sonepat (Table 2) and upto 1.0 t/h over average yields at Ludhiana (Table 3).

Recently Singh and Dwivedi (2006) demonstrated conservation of soil organic carbon, improvement in nitrogen use efficiency and increase in system yields through inclusion of pigeonpea in place of rice. The wheat yields following pigeonpea were found to be significantly greater than those following rice. The studies also found that wheat in the pigeonpea–wheat system needed less dosage of fertilizer N than those for the rice–wheat system, owing to increase in N supply, greater N use efficiencies and better growth

Table 2. Days to maturity, grain yield and pod borer damage in ESDP and SDP pigeonpea cultivars in Sonepat, Haryana, and the performance of wheat following pigeonpea, rainy seasons, 1996 and 1997[a].

Genotype	Pigeonpea				Wheat	
	No. of observations	Mean days to maturity	Grain yield (t/ha)	Pod borer damage (%)	Days to maturity	Grain yield (t/ha)
ESDP						
ICPL 85010	14	154	1.35	21.7	142	4.48
ICPL 88039	18	157	1.57	7.5	142	4.68
SDP						
Manak (Control)	18	176	1.40	15.5	133	3.93

[a] Based on Dahiya et al. 2002.

Table 3. Days to maturity, grain yield and 100-seed mass of three ESDP and one SDP, cultivars and performance of wheat cultivar (HD 2329) following pigeonpea at Ludhiana, rainy season, 1996[a].

Genotype	Pigeonpea			Wheat
	Days to maturity	Grain yield (t/ha)	Seed weight (g/100-seed)	Yield (t/ha)
ESDP				
ICPL 85010	144	1.58	8.8	4.70
AL 201	144	1.60	6.8	4.90
ICPL 88039	144	1.69	9.0	4.85
SDP				
T 21	170	1.66	6.8	3.86

[a] Based on Dahiya et al. 2001 and 2002.

environment. The results of on-farm study provided empirical evidence that ESDPs could contribute to higher productivity of the pigeonpea–wheat rotation systems. Most of the farmers who participated in on-farm trials in Sonepat preferred ESDP variety ICPL 88039 to any other SDP cultivar for its early maturity, bold seed size and greater yield of the following wheat crop (Dahiya et al. 2002).

Expansion of ICPL 88039 in the Indo-Gangetic Plains: 2000-2006

After exploratory trials with the indeterminate ESDP genotype ICPL 88039 were completed in Sonepat, Ghaziabad and Ludhiana, more on-farm trials were conducted in farmers' fields to promote its adoption and expansion. The locations chosen were in the districts of Ghaziabad, Meerut and Bulandshahr in Uttar Pradesh in the North-western Indo-Gangetic Plains; and at selected locations in eastern Uttar Pradesh and Bihar in North-eastern Indo-Gangetic Plains. Farmers' participatory on-farm evaluation of ICPL 88039 was also conducted at selected locations in the district of Kanpur Dehat in central Uttar Pradesh; and in the districts of Guna and Lalitpur in Madhya Pradesh (Figure 4).

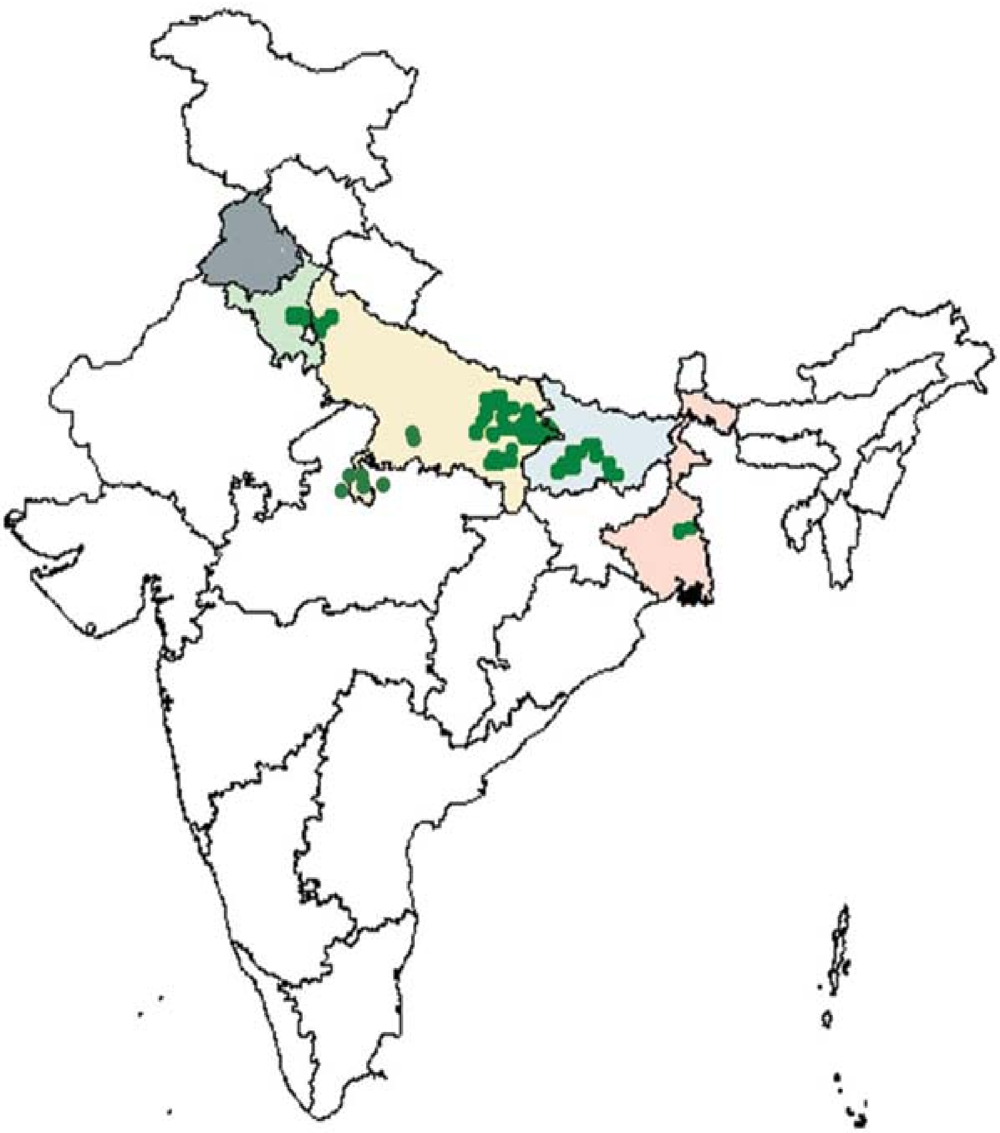

Figure 4. Expansion of ICPL 88039 in the Indo-Gangetic Plains of India.

Adoption and expansion in the North-western IGP

After ESDP genotype ICPL 88039 was formally introduced to villages in Haryana and western parts of Uttar Pradesh through farmers' participatory on-farm and integrated pest management (IPM) trials, studies were made to quantify its spread and uptake. Seed multiplication, seed distribution, seed sale and random verification of net sown area were used to estimate the area planted to genotype ICPL 88039. Figure 5 and Figure 6 present its expansion and adoption in Sonepat, Meerut and Ghaziabad during 2001 and 2005.

A total of 94 farmers in the districts of Sonepat in Haryana, and Ghaziabad, Bulandshahr and Meerut in Uttar Pradesh in western IGP (Table 4) were interviewed (Figure 7) and > 3000 ha was found sown with pigeonpea, mostly (70-90%) with ESDP variety cultivar ICPL 88039. The crops were critically observed to further quantify constraints and opportunities for further expansion of this cultivar in the RWCS (Figure 8).

More than 4.5 tons of seed was sold during 2004, and 70 tons in 2005-06, all of which have now covered an additional area of approximately 2500 ha. This

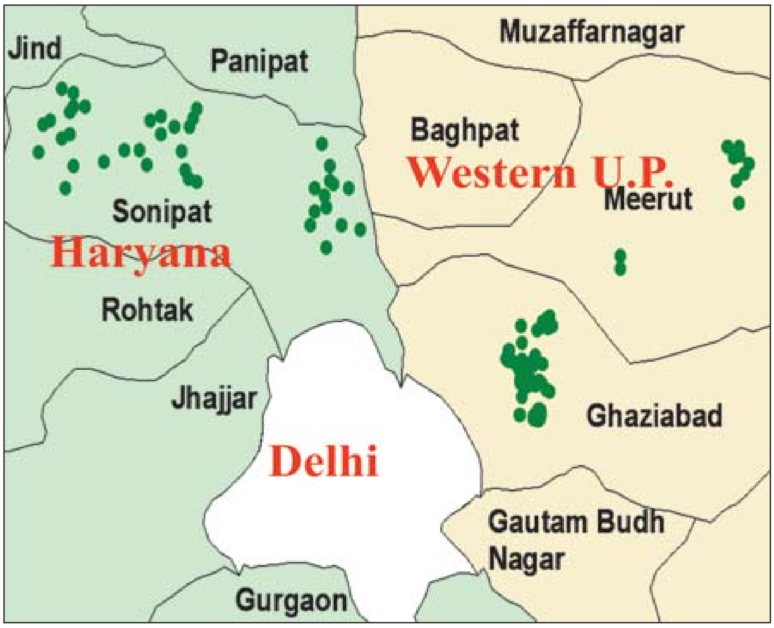

Figure 5. Spread of ICPL 88039 in western Uttar Pradesh, in North-western IGP, India.

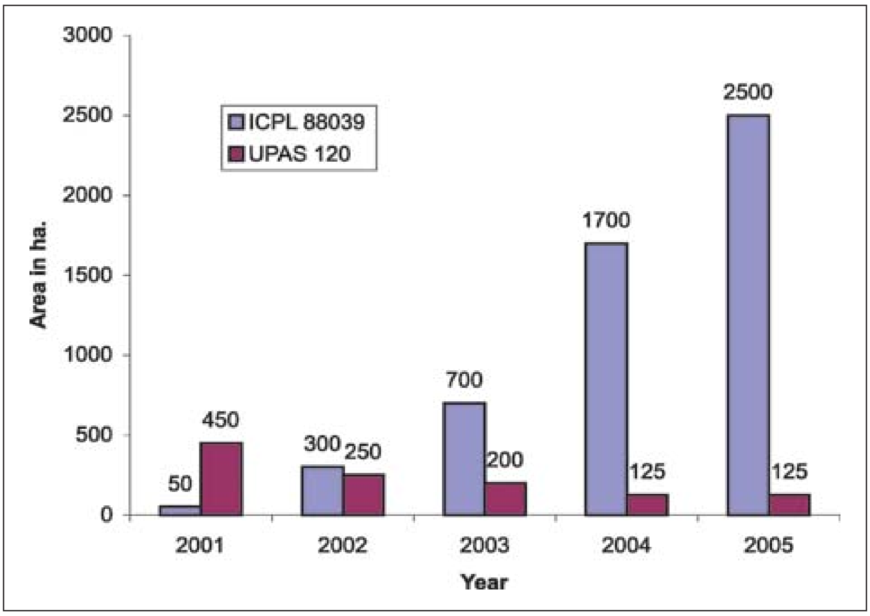

Figure 6. Expansion and adoption of ESDP variety ICPL 88039 in Sonepat (Haryana) and Meerut and Ghaziabad (Uttar Pradesh), in North-western IGP, 2001-2005.

Table 4. Number of farmers and area (ha) sown with pigeonpea in four districts in Haryana and Uttar Pradesh, 2004.

Location	Farmers (no.)	Area under Pigeonpea (ha)	
		UPAS 120	ICPL 88039
Sonepat	42	2	210
Ghaziabad	37	5	111
Bulandshahr	8	2	16
Meerut	7	-	10
Total	94	9	347

Figure 7. Farmers' participatory varietal trial, ICPL 88039, Meerut, western Uttar Pradesh.

Figure 8. Critical observations and evaluation of ICPL 88039, Ghaziabad, western Uttar Pradesh.

makes it even more essential to establish a self-contained seed system with focus on maintaining the purity of ESDP genotype ICPL 88039 during seed multiplication and trading at the village level.

Adoption and expansion in the North-eastern IGP

In the North-eastern plains of eastern Uttar Pradesh, Bihar and West Bengal, pigeonpea is grown as a rainfed crop and more than 90% of the area is covered under long duration or SDP varieties. Several of these varieties (Type 7, Type 17, Birsa Arhar 1, Laxmi etc.) were found to be susceptible to Sterility Mosaic Virus Disease and SDP varieties (Bahar, Pusa 9, DA 11 and MA 2) released to replace these varieties could not facilitate timely sowing of winter crops such as wheat. Additionally these varieties were found to be susceptible to sterility mosaic and wilt diseases, and highly susceptible to pod borer.

The successful testing of ESDP variety ICPL 88039 triggered the expansion of the variety in the North-eastern plains of IGP. In 2005 and 2006, we initiated preliminary farmers' participatory evaluations of this variety in several villages/districts in eastern Uttar Pradesh, Bihar and West Bengal (Figure 9). The ESDP variety ICPL 88039 was evaluated for its suitability to precede the

Figure 9. Spread of ICPL 88039 in eastern Uttar Pradesh, Bihar and West Bengal in North-eastern IGP, India.

second crop of wheat and for its pest resistance, with traditional and improved tillage practices specifically (bed planting). A total of 625 and 428 on-farm trials were conducted in 12 and 10 districts of eastern UP and Bihar respectively. It was also introduced into 14 farmers' fields in three districts of West Bengal in the 2006 rainy season (Table 5). It was found to be a suitable and profitable replacement for rainfed rice followed by timely planting of wheat throughout locations in eastern UP and South-eastern Bihar

Table 5. Evaluation of ICPL 88039 in farmers' fields in eastern Uttar Pradesh, Bihar and West Bengal[a].

Region	District (no.)	Farmers (no.)	Area (ha)	Yield[a] (t/ha)	Farmers' perception
Eastern UP[b]	12	625	207	1.10 – 1.64	+++
Central UP and MP	4	27	220	1.60 – 2.20	+++
Bihar[c]	10	428	121	0.84 – 1.58	++
West Bengal[d]	3	14	4[e]	-[e]	-[e]

[a] Based on 2004 and 2005 on-farm trials;
[b] Districts: Pratapgarh, Batlia, Mau, Varanasi, Mirzapur, Chandauli, Ambedkarnagar, Faizabad, Basti, Gonda, Baharaich and Sultanpur;
[c] Districts: Patna, Jehnabad, Jamui, Lakhisarai, Banka, Munger, Muzaffarpur, Samastipur, Bojpur and Vaisali;
[d] Districts: Burdan, Birbthum and Nadia;
[e] Introduced for preliminary trials in the 2006 rainy season (sown, crop looks impressive, data awaited)
+++ Suitable in uplands in normal rainfall when season begins 1st week of June;
++ Most suitable for rainfed upland rice in the south-eastern Bihar plateau.

(Figure 10). Also the ESDP variety ICPL 88039 was found to be resistant to wilt and responsive to economical management of pod borer with two insecticidal sprays.

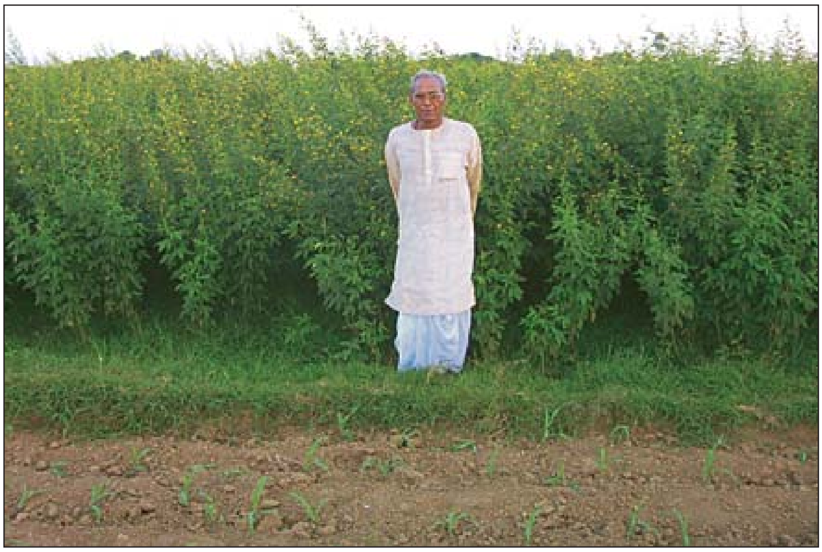

Figure 10. Farmers' participatory varietal trial, ICPL 88039, Jehanabad, Bihar.

Adoption and expansion in central Uttar Pradesh and Madhya Pradesh

In 2004-05 for the first time 5 kg seeds of ICPL 88039 were given to a farmer Mr Lal Singh of village Semara Bujurga, Lalitpur, Uttar Pradesh, a location that adjoined neighboring Madhya Pradesh. The crop performance was not encouraging up to 70-80 days of sowing and the first flush of flowers and pods were attacked by blister beetel (*Mylabris pustulata*). However, the crop recovered and the second flush of flowers gave an impressive produce of 3 tons/hectare. Mr Lal Singh eventually become the seed and technology source for rest of the farmers in this village. The news of ICPL 88039's performance spread to adjoining villages of Lalitpur in Uttar Pradesh and Madhya Pradesh; and within two seasons, about 27 farmers have started growing ICPL 88039 in two districts of Madhya Pradesh (Guna, Tikamgarh) and two districts of Uttar Pradesh (Lalitpur and Kanpur Dehat) (Figure 11). According to an estimate, the variety has been grown in about 220 hectares during the 2006 season and is expanding at an exponential rate. This has triggered the demand for seed among the farmers in these districts as well as and adjoining districts in these states.

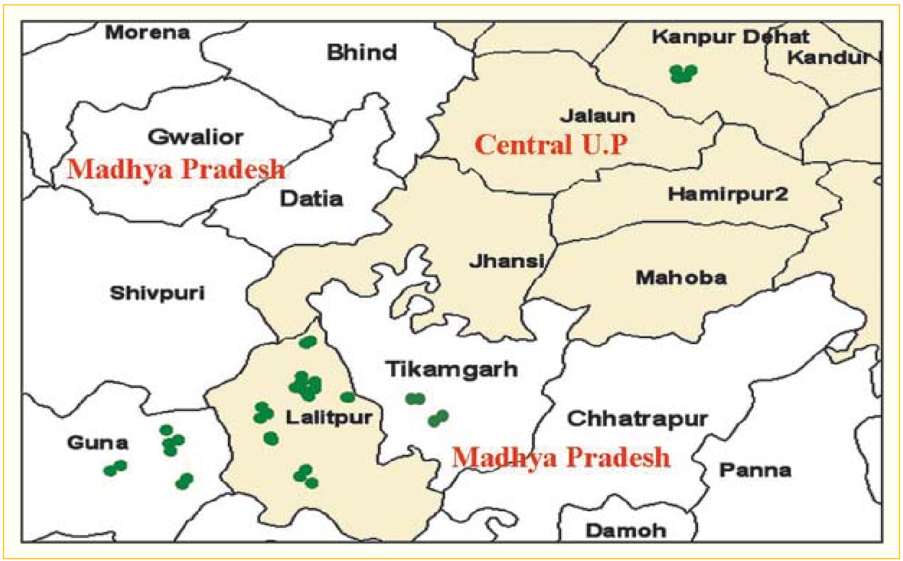

Figure 11. Spread of ICPL 88039 in central Uttar Pradesh and Madhya Pradesh, India.

New crop establishment methods and ICPL 88039

Traditionally, pigeonpea is grown on flat beds. In eastern IGP and parts of central and northern IGP, the crop often suffers due to water logging and poor drainage. In the initial stage of crop growth, seedling mortality due to poor aeration and incidence of phytophthora blight (*Phytophthora drechsleri* f. sp. *cajani*) is very common. This in turn leads to poor plant stands and consequently, low yields. The introduction and expansion of raised bed system of planting proved to be a favorable technology for profitable pigeonpea cultivation. Raised bed planting of ESDP variety ICPL 88039 has proved very effective in realizing higher yields by ensuring the desired plant stand and minimizing the incidence of phytophthora blight. Since 2000, attempts have also been made to establish ESDP variety ICPL 88039 using recently introduced resource conservation technologies (RCT) such as raised bed planting (Figure 12), reduced tillage and zero tillage in rice–wheat systems. The technology of raised bed planting of ESDP variety ICPL 88039 in RWCS improves drainage, efficiency of water and fertilizer, and addresses the problem of rainwater conservation in the rainy season. We quantified and examined the effects of introducing new tillage and RCTs. Attempts were also made to examine the introduction of this legume for organic carbon sequestration during the dry-to-wet transition in rice–wheat systems and to conserve and recycle soil-N and explore possibilities of mopping up residual soil-N before it is leached out of the root zone during the monsoons, leading to contamination of the ground water aquifers (Singh and Dwivedi 2006).

Figure 12. The ESDP variety ICPL 88039 on raised beds in IGP.

Raised bed planting and ICPL 88039

In the IGP, rainfall events of varying intensity and duration occur. Often rainfall leads to water stagnation and excessive moisture conditions. As a consequence most kharif crops except rice suffer from water logging. In order to avoid crop losses due to temporary water logging, farmers often prefer to grow rice. Another reason why rice is not easily replaced is the traditional system of planting crops on flat beds. In farmers' participatory field trials we evaluated the potential of ESDP cultivar ICPL 88039 on raised beds during the main monsoon season in nearly 34 ha in Meerut and Ghaziabad districts. Pigeonpea cultivar ICPL 88039 was established with four different crop establishment methods: raised bed, zero till in un-ploughed field, line sowing and the conventional method. The results showed that bed planting can significantly increase yields and prove helpful in promoting pigeonpea to substitute rice (Figure 13).

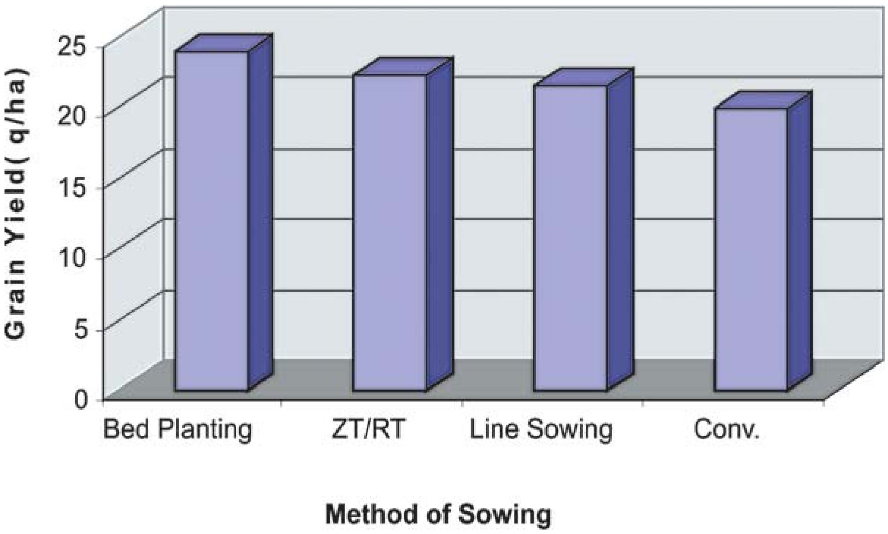

Figure 13. Performance of ESDP variety ICPL 88039 with different sowing methods [bed planting (raised beds), zero tillage/reduced tillage (ZT/RT), line sowing and conventional (broadcasting) or behind the plough] in Meerut and Ghaziabad, western Uttar Pradesh.

Further, ICPL 88039 was also evaluated with other pigeonpea varieties with different planting methods where raised bed was found best in comparison with all other planting methods and ICPL 88039 performed better than UPAS 120 in both raised and flat bed planting methods. In addition, ICPL 88039 contributed more N compared to UPAS 120. It was recorded that the seed yield of ICPL 88039 (2.6 & 2.2 t/ha) was higher compared to UPAS 120 (2.2 & 1.8 t/ ha) both under raised and ZT/RT flat bed planting systems (Fig. 13, Table 6). Data related to leaf litter fall, N contribution and crop productivity was also recorded. Data revealed that (Table 7) irrespective of the crop variety, the litter fall and N recycling through litter was higher under bed planting compared to flat planting.

Sowing time, maturity, and ICPL 88039

The recommended practice is to sow pigeonpea in the second half of June. However, farmers begin to sow it as early as the last week of April. Those with irrigation facilities prefer to sow pigeonpea early so that pigeonpea fields are not severely infested by weeds such as *Trianthema monogyma*. Chemical weed control is not popular and hand weeding is hindered by rainfall and so, late June-July sowings tend to be badly infested by this weed. Crops sown in April-May generally mature 15-20 days earlier and produce more biomass (stalks), total dry matter and grain yield than those sown in mid June-July. Additionally, early sowings ensure that wheat can be sown by 20 November. However, the potential of the early-sown crop is limited as it needs several irrigations and hence is not economical to farmers. Further, plants also grow tall (> 3 m) posing problems for insect-pest control.

Table 6. Effect of pigeonpea varieties and methods of planting on seed yield (t/ha).*

Planting method	Days taken to maturity		Seed yield (t ha^{-1})	
	ICPL 88039	UPAS 120	ICPL 88039	UPAS 120
Raised bed	141	155	2.6	2.2
Flat bed	139	154	2.2	1.8
Mean	140.0	154.5	2.4	2.0

* Based on data from 54 farmers' fields and 2.2 ha.

Table 7. Effect of pigeonpea varieties and methods of planting on litter fall and N recycling.*

Planting method	Litter fall (kg/ha)		N content in litter (%)		N recycling through litter (kg/ha)	
	ICPL 88039	UPAS 120	ICPL 88039	UPAS 120	ICPL 88039	UPAS 120
Raised bed	1690	1575	1.57	1.55	26.53	24.41
Flat bed	1620	1408	1.56	1.55	25.43	21.82
Mean	1655.0	1491.5	1.57	1.55	25.98	23.12

* Based on data from 54 farmers' fields and 2.2 ha.

To test the suitability of ESDP variety ICPL 88039 over SDP variety UPAS 120, systematic on-farm experiments were conducted in different locations in Haryana and western Uttar Pradesh during 2004. Sowing dates of different on-farm trials as well as other farmers' fields ranged from 1 May to 20 June. In most cases, pre-sown irrigation was provided to pigeonpea irrespective of genotype. Seeds were sown in rows that were 40 cm apart, giving a final stand of 10-12 plants/sq m**.** A few farmers sowed pigeonpea on beds as well. Detailed observations were made on growth stages of the crop and characteristics of both genotypes in farmers' fields. Based on data provided, the date of sowing and physiological status of the crop, the minimum duration of the SDP variety UPAS 120 sown in first week of June or earlier was about 155 days (Table 8). Sowing the genotype earlier seemed to delay maturity, primarily because pigeonpea is photoperiod-sensitive. The ESDP variety ICPL 88039 sown during the same period matured 20-25 days earlier than UPAS 120. ESDP variety ICPL 88039 showed stability over different dates of plantings (Fig. 4, Table 8) and remained 2 m tall.

Data collected from about 289 farmers' fields at different dates of sowings indicated that there was little decrease in yield of pigeonpea variety ICPL 88039 with delayed planting up to the first week of July (Figure 14). Data also indicate that yield of ICPL 88039 was more under zero-till conditions.

Table 8. Duration to maturity of two pigeonpea genotypes in Haryana (Sonepat), and western Uttar Pradesh (Ghaziabad, Bulandshahr and Meerut) North-western IGP, 2004.

Location	Sowing period	Duration to maturity (days)	
		UPAS 120	ICPL 88039
Sonepat	May – June	155-180	135-150
Ghaziabad	May – June	155-185	130-155
Bulandshahr	May – June	150-170	130-145
Meerut	May – June	160-180	135-150

Date of sowings ranged from the first week of May to the second week of June.

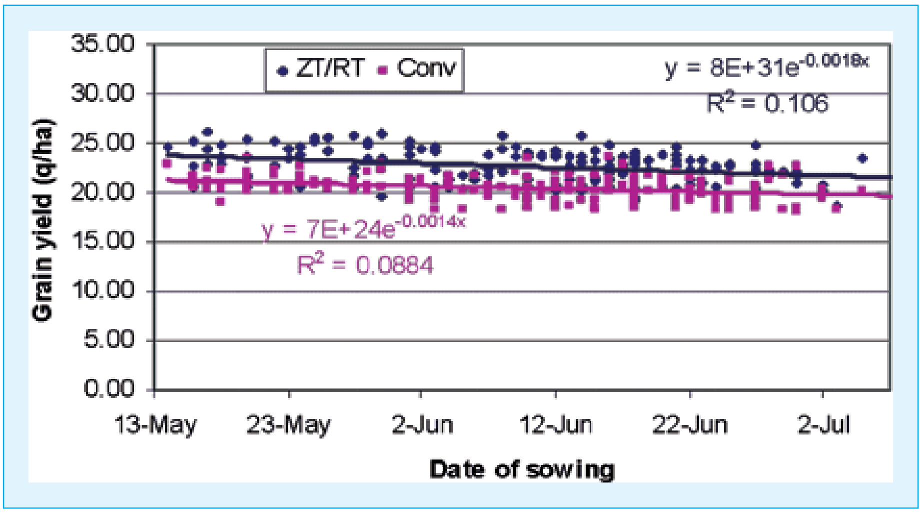

Figure 14. Effect of sowing time and planting methods on pigeonpea productivity.

Water productivity and ICPL 88039

The new ESDP genotype was evaluated for water productivity under raised bed planting and compared with traditional flat bed broadcasting method of crop establishment through farmers' participatory trials. The average productivity of pigeonpea was comparatively less during 2005 than 2004 due to unfavorable weather, particularly at the flowering stage. Data recorded from 55 participatory trials in western Uttar Pradesh revealed that the grain yield of pigeonpea was 23.2% higher with raised bed planting compared to farmers' practice of crop establishment. The water productivity (WP) in terms of basmati rice-equivalent yield was computed to compare pigeonpea with rice. Pigeonpea was remarkably more productive than rice. Among crop establishment methods, the WP was markedly better in raised beds as compared to flat bed planting (Table 9).

Constraints and opportunities for ICPL 88039 adoption

Constraints to the adoption of ESDP variety ICPL 88039 include: instability of production due to abiotic, biotic and socioeconomical factors over seasons, and varying performance over locations. Among abiotic constraints are water logging, alkalinity and long spells of drought at seedling stages. The major biotic factors responsible for the instability and reduced productivity of the genotype in the North-West Plain Zone (NWPZ) are insect-

Table 9. Comparative performance of ESDP ICPL 88039 with different crop establishment techniques in water productivity in the pigeonpea–wheat cropping system in western Uttar Pradesh, 2004-2005.

Crop establishment technique	Seed yield (t/ha)	Basmati rice equivalent yield (t/ha)**	Total irrigation (cu m/ha)	Basmati rice equivalent water productivity (kg/cu m)
Raised bed (fresh)*	1.75	3.48	775	4.48
Raised bed (permanent)è	1.73	3.44	745	4.61
Flat bed planting#	1.42	2.82	912	3.09
Mean	1.63	3.24	811	3.99

*Average of 14 farmers; èAverage of 02 farmers; #Average of 55 farmers **Calculated at maximum sale price of pigeonpea (Rs 13900/ton) and basmati rice (Rs 7000/ton) pests such as pod borers (*Maruca vitrata, Helicoverpa armigera*), and blister beetle (*Mylabris pustulata*) and diseases such as wilt (*Fusarium udum*) and sterility mosaic (SMD-virus).

The ESDP variety ICPL 88039 was identified as minimal management-responsive to pod borers. Additionally its variant – purified at ICRISAT (HC Sharma Personal Communication) and sown in selected farmers' fields in NWPZ – was found to be highly tolerant to pod borer. Further ICPL 88039 was found to be highly resistant to wilt and sterility mosaic diseases of pigeonpea. In comparison to ICPL 88039, UPAS 120 and other local varieties grown by farmers were found to be susceptible to wilt and pod borer. In addition to these pests, cercospora leaf spot (*Cercospora cajani*), phytophthora blight (*P. drechsleri* f. sp. *cajani*) and dry root rot (*Rhizoctonoa bataticola*) were also noticed in traces in farmers' fields sown with local cultivars other than ICPL 88039. To facilitate field diagnostics and management, major abiotic and biotic constraints along with socioeconomical issues that limit production of ESDP variety ICPL 88039 in RWCS are briefly described.

Abiotic constraints

Drought

Drought and waterlogging in the early vegetative phase can cause yield loss and sometimes result in crop failure. ESDP genotypes escape terminal drought due to their shorter life cycle, but they are, however, relatively more sensitive to intermittent drought stress (Nam et al. 2001). Occasionally drought occurs at around the seedling stage; in 2004, for instance, we found that ESDP variety ICPL 88039 has the unique capability of recovering from early season drought, and even compensating for it.

The year 2004 was unique in that false but substantial rainfall during the first week of May encouraged several farmers to plant their pigeonpea earlier than previous years. However, a majority of farmers planted their pigeonpea with the second spell of rainfall, which was on 27 May. Those who sowed pigeonpea in the first fortnight of May and were able to provide substantial life saving irrigations during the hottest months of June and July managed to save their crop. Apart from these exceptions, however, the entire SDP crop of UPAS 120 was severely affected. In comparison to SDP varieties such as UPAS 120 and other local cultivars, ESDP variety ICPL 88039 managed to escape drought injury with one or two irrigations while most other SDP varieties could not resist drought and suffered near total crop loss. Further observations on farmers' fields show that water deficit at the pod formation stage adversely affects synchrony; plots that suffered such water deficit matured 5-10 days later than those that did not suffer soil moisture stress although both were sown at the same time.

The ESDP variety ICPL 88039 has been bred to escape terminal drought and therefore showed good adaptation to environments with a shorter growing season. At ICRISAT, Patancheru, Andhra Pradesh, the ESDP variety ICPL 88039 has been found to be the best adapted to intermittent drought, even with periods coinciding with flowering and pod-filling stages. These aspects were confirmed by substantially higher yields (< 2.5 t/ha) of ICPL 88039 under drought conditions in on-farm trials in the North-western IGP areas during 2004. The season also confirmed the genotype's higher tolerance to drought. Further, in comparison to irrigated transplanted rice where needed irrigation for the survival of rice was not made available (Figure 15), ESDP variety ICPL 88039 was found to be better than rice when it came to providing incomes for subsistence farmers.

Figure 15. Drought tolerance of ICPL 88039 in comparison with rice.

Water logging

Pigeonpea is highly sensitive to water logging, which could result in considerable loss in crop vigor and plant stand (Chauhan 1987). The risk of crop failure or yield reduction due to short-term water logging is particularly acute in ESDP genotypes because they have less time to recover from the stress compared to medium or long duration cultivars (Matsunaga et al. 1991). To avoid water logging, it is recommended that ESDP variety ICPL 88039 be grown on raised beds.

Inadequate plant population

Uniformity of plant stand is an important aspect that determines yield in ESDP. Observation in farmers' fields at Sonepat revealed that plant population varied from 3 to 7 plants/sq m as against the optimum of 8 to 15 plants/sq m (Chauhan 1990). Among reasons responsible for such poor plant stands were the use of the broadcast method of sowing as well as the poor quality of seed used.

Nutrients

Pigeonpea generally exhibits no serious problem of nutrient deficiency and a basal dose of 100 kg di-ammonium phosphate (DAP) seems to satisfy immediate N and P needs. Generally, N from N-fixation and the use of residual nutrients in cropping systems are assumed to take care of additional requirement of nutrients.

Biotic constraints

Insect-pests

Gram pod borer (*Helicoverpa armigera*)

This insect destroys buds, flowers and pods. If flowers and pods are not available, larvae feed on foliage. Larvae prefer to feed on protein-rich seed inside the pods. Adult *H. armigera* have a wingspan of about 40 mm with dull brown forewings. A single female can lay up to 2000 small white eggs, usually singly on flower buds and young pods. Fully grown larvae are 30 to 40 mm long and have various body color and banding patterns. Pupation occurs in the soil or in plant debris. One generation takes four weeks in favorable conditions (Figure 16).

Control measures

Plant protection operations for ESDP variety ICPL 88039 must be initiated when one small larva or three eggs are observed per plant:

- Natural enemies of the pest, including vertebrate predators such as birds must be encouraged;

Figure 16. (A) Male (left) and female (right) moths of *Helicoverpa armigera,* (B) *H. armigera* eggs on chickpea leaves, (C) *H. armigera* damaging pigeonpea leaves and (D) pods.

- *H. armigera* phermone traps must be installed at the time of sowing for scheduling control strategies (5 moths per trap per day);
- Manual shaking of plants to dislodge larvae, hand picking and destruction of larvae helps minimize losses caused by this insect;
- Foliar application of Endosulfan @ 7 ml/ L water (300-500 L solution/ha) reduces insect population;
- Application of HNPV @ 500 LE/ha at peak infestation, and repetition of the same dose after 15-20 days controls the insect.

Spotted pod borer (*Maruca vitrata*)

Larvae feed from inside a webbed mass of leaves, buds and pods. This behavior makes *Maruca* a foliage feeder and pod borer. Adults have distinctive white bands on brown forewings with a wing span of 20 mm. Eggs are laid in small clusters of 10 to 15 on leaves, buds and flowers. A fully grown larva measures 25 mm in length with a pale body lined by rows of conspicuous black spots on its dorsal surface (Figure 17). Pupation takes place in

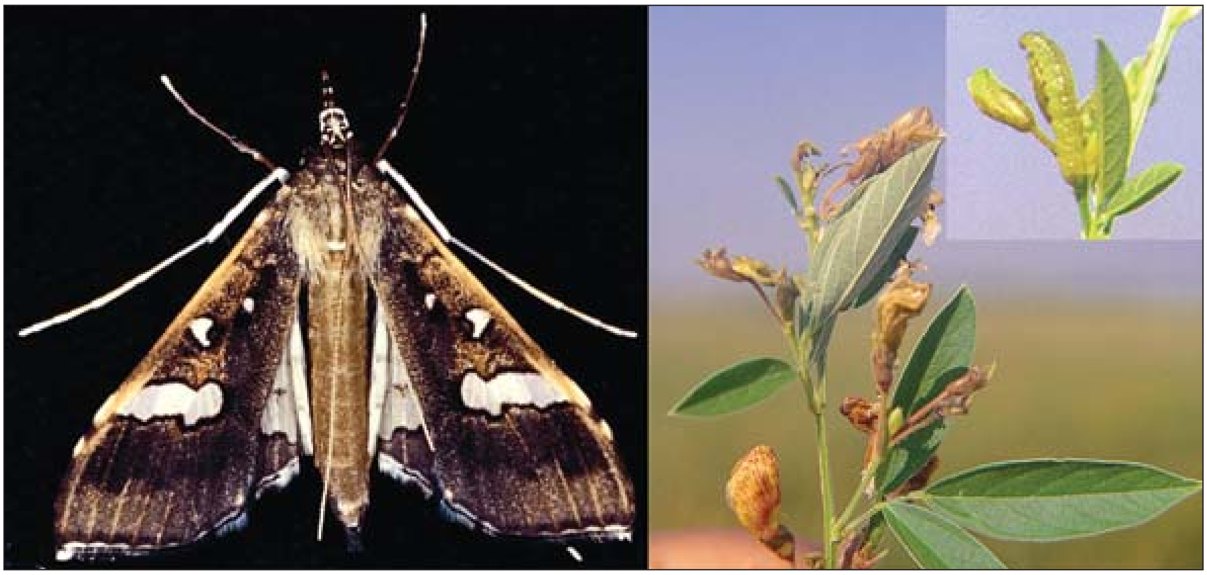

Figure 17. (A) *Maruca vitrata* adult, (B) *M. vitrata* larva (inset) feeds on webbed leaves and flower buds.

the web or on the soil surface in a silk cocoon. Under favorable conditions complete life cycle takes three weeks.

Control measures

- Foliar application of Avaunt @ 1 ml or Tracer @ 0.4 ml/L water (300-500 L chemical solution/ha depending upon vegetative growth);
- Chemical control is complicated by the fact that larvae live in well-protected webs. Systemic pesticides may be more effective than contact insecticides.

Blister beetle (*Mylabris pustulata*)

Adult beetles feed on flowers and tender pods and can have significant impact on yields especially those of extra short duration varieties such as ICPL 88039. Adults measure about 25 mm in length and have red and black alternating bands on the elytra and are brightly colored (Figure 18). Eggs are usually laid in the soil and the larvae feed on eggs of other soil insects such as grasshopper. Thus, the larvae are beneficial, while adults cause considerable damage to the crop.

Control measures

- Chemical control may fail because the beetles are large, robust and highly mobile;
- Manual picking and destruction of adult blister beetles is the only practical control measure.

Diseases

Phytophthora blight (*Phytophthora drechsleri f. sp. cajani*)

Cloudy weather, drizzling rain and temperatures around 25^0 C form a suitable environment for the infection and development of this disease. The fungus attacks younger plants and causes total mortality. Infected leaves show water soaked lesions, lose turgidity and then desiccate. Slightly sunken, brown to black lesions appear on stems and petioles; these lesions tend to girdle and then break the main stem and/or branches. Plants that are infected by blight, but not killed often produce large galls on stems especially at edges of the lesions (Figure 19).

Figure 18. (A) *Mylabris pustulata* adult, (B) Hand picking of blister beetles.

Control measures

Preventive measures to contain this disease include:

- Ploughing the field deeply during the hot summer months;
- Avoiding sowing the crop in the field in low-lying patches that are prone to water logging;
- Planting on raised beds to ensure good drainage;
- Seed treatment with Metalaxyl (Redomil) @ 3g/kg seed, followed by two foliar sprays with

Figure 19. (A) Phytopthora blight in the field, (B) Phytopthora blight symptoms on leaf, (C) Phytopthora blight lesions girdle the stems.

Matalaxyl at (@ 3g/L water and 300-500 L solution / ha) fortnightly intervals starting from 15 days after sowing, which provides good control.

Fusarium wilt (*Fusarium udum*)

Wilt occurs mostly at the flowering stage of the crop and can cause complete yield loss in susceptible cultivars. The fungus infects the plant through root hairs and colonizes the vascular system causing brown to black discoloration of xylem, yellowing of leaves and eventually, death of the plant. A typical purple band is seen on the stem and lower branches of infected plants. The purple band on the stem is not visible on young wilted plants but internal xylem browning is clearly visible (Figure 20).

Control measures

- Ploughing the field deeply during hot summer months;

Figure 20. Impact of Fusarium wilt (A) Patches of wilted plants in the field, (B) purple bands extending upwards on the stem, and (C) browning of the xylem.

- Collection and burning of the wilted plants from the field;
- Follow crop rotation with non-host crops such as sorghum maize and rice for more than three years;
- Intercropping with sorghum, which reduces wilt incidence;
- Seed treatment with Benlate T or Benlate + Thiram (1:1) @ 2 g/kg seed, which completely eliminates seed-borne inoculums of the fungus.

Collar rot (*Sclerotium rolfsii*)

High soil moisture and temperature around 30^0 C at seedling stage of the crop encourages the disease. The disease is more common when undecomposed organic matter of the previous cereal crop is left on the soil surface. Collar rot normally is a seedling disease and causes rotting at the collar region resulting in death of seedlings. Dead seedlings show whitish mycelial growth of the fungus at the collar region. Sometimes white or brown sclerotial bodies of the fungus can be seen attached to the collar region of the plant or in the soil around it (Figure 21).

Figure 21. Collar rot infected plants in the field.

Control measures

- Removal of undecomposed debris of the previous crop and deep ploughing during the hot summer months reduces disease incidence;
- Seed treatment with Captan or Thiram @ 3 g/kg of seed helps in controlling the disease.

Powdery mildew (*Oidiopsis taurica [Leveillula taurica]*)

The disease develops at temperatures ranging from 20 to 35^0 C but 25^0 C is the optimum. A cool humid climate is congenial to fungal infection and colonization, but warm humid climate is favorable for sporulation and spore dispersal. Infected plants have white powdery fungal growth on all aerial parts ie, on leaves, flowers and pods. Severe infection results in heavy defoliation. Initial symptoms show up as small chlorotic spots on the upper surface of the leaves, and subsequently the corresponding lower surface develops white powdery patches, which gradually covers the entire leaf surface (Figure 22).

Control measures

- Selection of a field away from perennial pigeonpea crops affected with the disease;
- Late sowing (after July) in endemic areas reduces disease incidence;
- Foliar application of wettable sulphur @ 1 g or Triadimefon (Bayletan 255 EC) @ 0.03 %/L water and 300 to 500 L chemical solution/ha reduces disease severity.

Alternaria leaf spot and blight (*Alternaria tenuissima, A. alternata*)

Alternaria leaf spot and blight (*Alternaria tenuissim., A. alternata*) is not greatly significant in the main kharif crop but assumes serious dimensions in the late sown,

Figure 22. Pigeonpea plants infected with powdery mildew showing defoliation and leaflet with symptoms.

postrainy (pre-rabi) season in September, when pigeonpea is mostly sown in eastern India. Precise information on losses caused is not available; however, the disease causes significant yield losses in susceptible varieties like Bahar, which shows heavy defoliation under severe infection. Two species of *Alternaria viz., A. tenuissima* and *A. alternata* are reported to cause leaf blight in India (Kannaiyan et al. 1984, Reddy et al. 1990). The characteristic symptoms are concentric leaf spots of dark and light brown rings with a wavy and purple margin. Under severe infection these spots increase in size, coalesce and cause leaf blight. The lesions may appear on all aerial parts including pods. As a result of defoliation and drying, a grayish spore mass is observed on the lesions (Figure 23).

Control measures

- Early sowing and use of disease-free seeds help reduce the disease;
- Seed treatment with Mancozeb or Carbendazim or Captan or Thiram or Benelate T and antagonist *Trichoderma viride* has been reported effective in controlling seed-borne infection (Kumar et al. 2000).

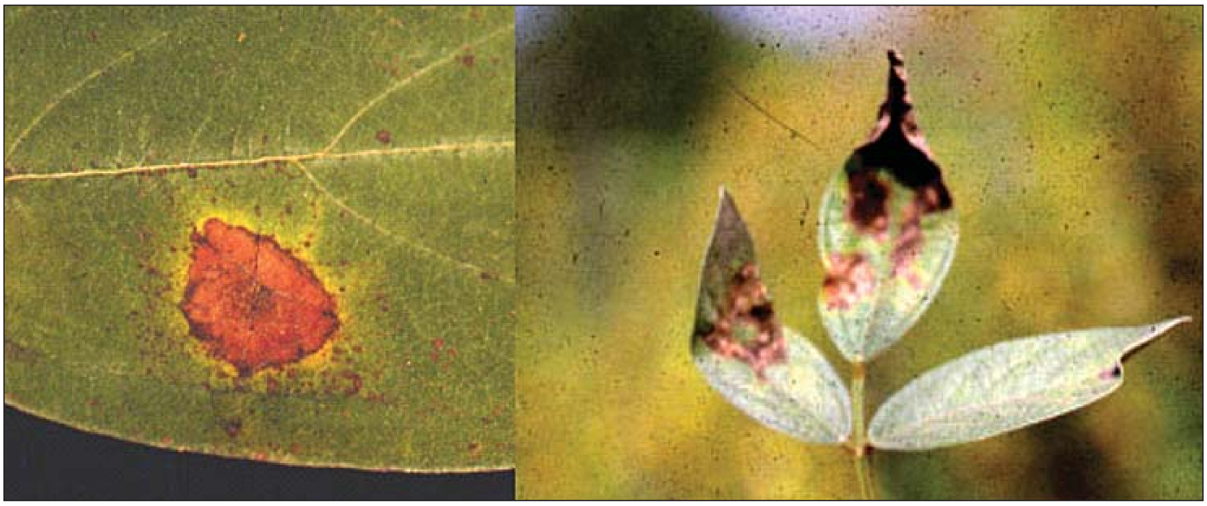

Figure 23. Necrotic symptoms of Alternaria leaf spot and blight on leaves.

Sterility mosaic *(Pigeonpea sterility mosaic virus)*

The disease is caused by pigeonpea sterility mosaic virus (PSMV) and is transmitted by eriophyid mite *Aceria cajani*. The disease can be easily recognized in the field as patches of stunted, bushy, pale green plants without flowers and pods. Leaves of the infected plants are small and show a light or dark green mosaic pattern. The pathogen and the vector survive in summer pigeonpea crops during the off-season. Mites spread with wind up to 2 km and infect plants in the vicinity. Some varieties such as ICP 2376 exhibit ring spot symptoms on leaves indicating localized infection and such plants produce normal flowers and pods (Figure 24).

Control measures

Preventive steps to contain this disease include:

- Destroying the sources of sterility mosaic inoculum ie, perennial or ratooned pigeonpea; infected plants must be uprooted at an early stage of disease development and destroyed;
- Following crop rotation with non-host crops to reduce sources of inoculum and mite vector;
- Treating seed with 25% Furadan 3G® or 10% aldicarb @ 3 g/kg seed;
- Foliar application of acaricides or insecticides like Kelthane®, Metasystox® @ 0.1% to control mite vector in the early stages of crop growth.

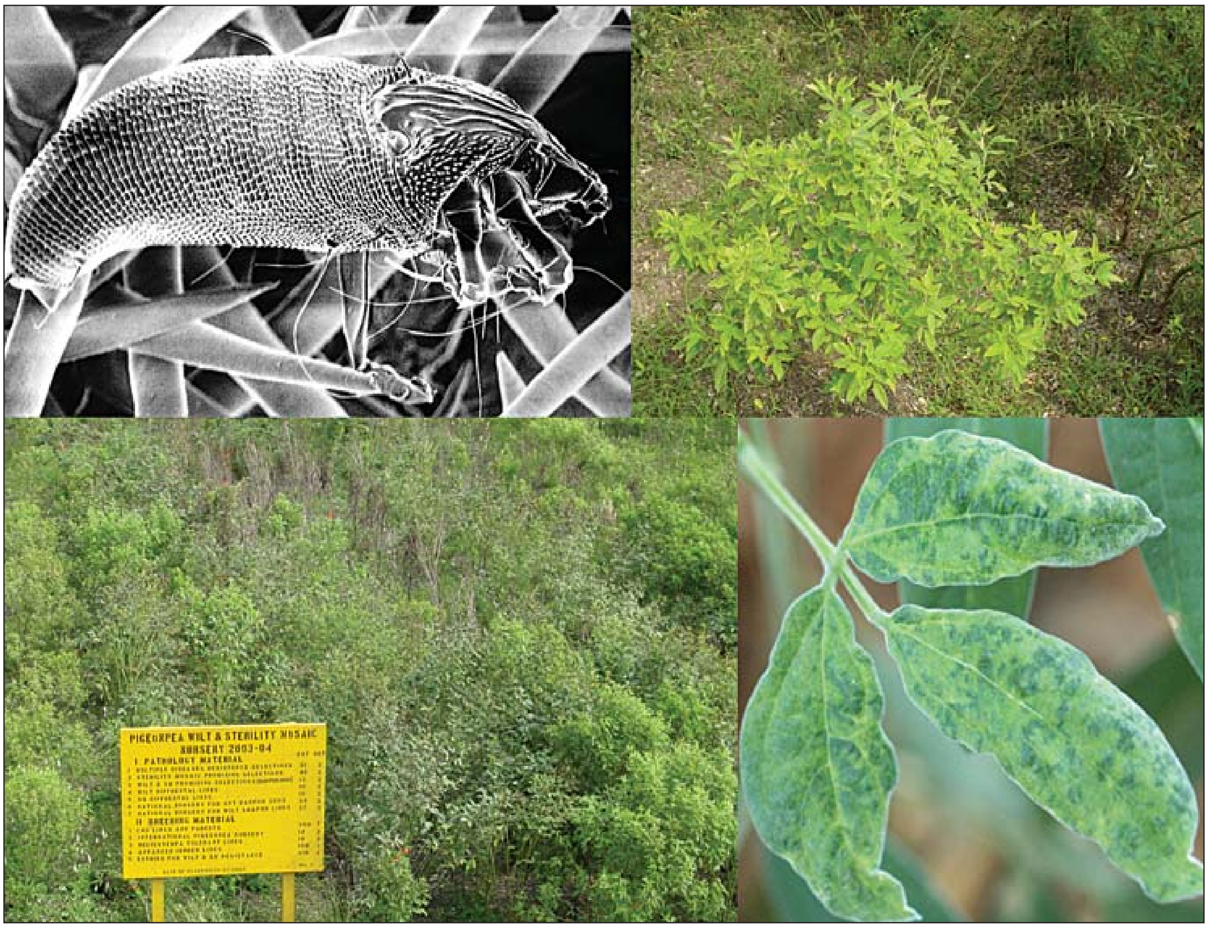

Figure 24. (A) A single eriophyid mite vector, (B) sterility mosaic field screening, (C) a single plant infected with sterility mosaic and (D) sterility mosaic symptoms on leaf.

Socioeconomic and policy constraints

Most farmers in RWCS tend to grow pigeonpea on marginal lands in rainfed conditions, and the crop does not receive much purchased inputs. Farmers have become market-conscious and prefer to grow crops that provide them assured returns on their more productive lands. Large fluctuations in market prices (that depend on production swings) influence farmers to switch from legumes to other crops such as rice. Pigeonpea is less profitable than rice in the western IGP under the existing policy regime and available technological options (Malik 1994). Farmers generally view pigeonpea as relatively more risky than rice during the rainy season, especially due to its susceptibility to insect pests, waterlogging and lack of price support.

Farmers lack knowledge of recently developed and released improved cultivars (Joshi 1998) and how to procure their seed. Cultivars such as AL 15, AL 201, ICPL 85010 and Paras have not been well adopted in farmers' fields. Presently, private sector seed companies do not consider production of pigeonpea seed a remunerative business. As a result, farmers often use their own seed for the next season or exchange with other farmers.

Infestation by bruchids (*Callosobruchus* spp.) during the crop season, harvesting and threshing generally results in seed damage. Improper storage conditions also make seed prone to damage by other insects and fungus. Rainfall at maturity may also damage seed quality. Thus, inferior seed results in poor germination, low plant stand and low yield. These seed related constraints also discourage farmers from growing pigeonpea instead of rice.

Additionally, research activities on development of pigeonpea genotypes and seed production are not linked to extension programs. Such linkages at early stages of technology are necessary for effective transfer of appropriate technology to farmers. This approach would enable farmers become acquainted with the latest technology that may suit their circumstances, and give researchers and extension personnel feedback on problems in the adoption of technology in their specific context.

The development of ESDP variety ICPL 88039 and its profitable production is a new agro-technology and accordingly, agro-techniques need to be evaluated and fine-tuned for farmers' specific circumstances and needs. For instance, certain practices are recommended to farmers for higher yields; failure to adhere to the technology presented, ie, lack of seed treatment, inappropriate fertilizer application, deviance from the prescribed sowing time and population densities, and insufficient weeding will inevitably lead to low yields. Postharvest handling is also a major constraint to the adoption of ESDP variety ICPL 88039 because seed needs to be stored properly for a long period. Storage and processing are often inadequate, and losses can be heavy.

Farmers' perceptions of ICPL 88039

In the last few years, scientists from ICAR institutions, state universities, RWC and ICRISAT have formally and informally interacted and interviewed several farmers to understand their perceptions of ESDP variety ICPL 88039 versus SDP (UPAS 120 and Manak) in the districts of Sonepat, Ghaziabad, Bulandshahr, Meerut, Lalitpur and parts of eastern IGP.

- More than 85% indicated that the early maturity of ESDP ICPL 88039 was a major advantage;
- About 78% suggested that pest incidence was lower in the indeterminate ESDP ICPL 88039;
- Nearly 80% indicated that they obtained higher yield from wheat following ESDP variety ICPL 88039 (Table 10);

Table 10. Farmers' perceptions (%) about ESDP genotype ICPL 88039 in comparison with SDP UPAS 120 and other pigeonpea cultivars.

	Response (%)			
Characteristics	Better	Similar	Poor	Can't say
Yield	55	45	-	-
Seed size	95	2	-	3
Price	30	65	-	5
Days to maturity	85	10	-	5
Pod borer	88	5	-	7
Diseases	90	5	-	5
Fuel wood	30	70	-	-
Taste	45	20	-	35
Wheat crop	80	20	-	-
Drought	60	30	-	-
Investments/inputs	-	90	-	10

- Only 55% of farmers indicated that ESDP has any yield advantage over SDP;
- Almost 45% of farmers who consumed ESDP preferred its taste to SDP or other long duration genotypes grown in the surveyed area;
- About 75% preferred indeterminate ESDP cultivar ICPL 88039 to any other cultivar;
- A number of farmers indicated that they had been persuaded by the female members of their family to grow pigeonpea because of its potential as an available and relatively cheaper source of fuel. Dried pigeonpea stems, according to them, have excellent burning quality and produce less smoke than other available fuel sources;
- A small percentage of farmers, however, indicated that stick yield from ESDP types was less than with SDP types;
- About 95% of the farmers interviewed during 2004 had preferred ESDP ICPL 88039 over SDP types UPAS 120; only 5% of these had also sown SDP during 2004, thereby indicating increased preference and uptake of ESDP variety ICPL 88039 over any other genotype of pigeonpea;
- Most farmers harvested > 2 t/ha grain from ESDP variety ICPL 88039.

Optimum agronomic management for ICPL 88039 production

To realize the yield potential of high yielding pigeonpea varieties, specifically appropriate agronomic management is essential. Of the several factors that effect of crop productivity, agronomic components such as proper soil tilling, adequate plant population, optimum time and method of sowing, nutrient supply, and water and weed management are very important (Chauhan 1990; Sekhon and Singh 2005). Although no specific agronomic package has been developed for ESDP variety ICPL 88039, attempts have been made to list recommended practices for the production of ESDP variety ICPL 88039 production (Table 11), based on its performance at different locations under various agronomic practices.

Table 11. Recommended agronomic practices for the production of ESDP variety ICPL 88039.

Description of work	Recommended practice
Land preparation	Plough the field to a depth of 15-20 cm followed by 2 to 3 cross-harrowings; level the field for proper drainage
Fertilizer	A basal dose of 18 kg N and 20 kg P/ha
Seed	Select pure and healthy seed of the cultivar ICPL 88039 with > 90% germination
Seed dressing	Carbendazim + Thiram (1:1) @ 3 g/kg seed for wilt and root rots; Metalaxyl @ 3g/kg seed for Phytophthora blight; also seed treatment with Rhizobium improves nodulation
Sowing time	Last week of May to mid-June
Seed rate	15 kg/ha
Spacing	40 cm inter- and 20 cm intra-row (12 to 15 plants/sq m)
Intercropping and	Intercropping with mungbean, black gram or maize is economical and can be rotated
rotation	with wheat, late sown potato and chickpea
Water management	Pre-sowing irrigation for May-sown crop essential; irrigation is beneficial if prolonged drought persists. Bed planting is recommended for water management
Weed control	Pre-emergence application of pendimethalin @ 1 kg ai/ha; manual weeding once or twice during early growth stage
Insects	
Spotted pod borer (*Maruca vitrata*)	Foliar application of Avaunt @ 1 ml or Tracer @ 0.4 ml or Endosulfan @ 2 ml/L and 300-500 L chemical solution/ha depending on vegetative growth
Gram pod borer (*Helicoverpa armigera*)	Foliar application of Avaunt @ 1 ml or Tracer @ 0.4 ml or Endosulfan @ 2 ml/L and 300-500 L chemical solution/ha depending on vegetative growth
Diseases	
Phytophthora blight	Seed treatment with Metalaxyl followed by two foliar applications of Metalaxyl at 15-day intervals starting from 15 days after emergence
Fusarium wilt	Seed treatment with Carbendazim + Thiram (1:1) @ 3 g/kg seed
Collar rot	Seed treatment with Captan @ 3 g/kg seed
Powdery mildew	Foliar application of wettable sulphur @ 1g/L or Triadimefon (25 EC) @ 0.03%/L water and 300 to 500 L chemical solution/ha depending vegetative growth
Sterility mosaic	Foliar application of acaricide or insecticide like Kelthane or Metasystox @ 0.1% to control mite vector in the early stages of the plant growth
Harvest	Harvest the crop when fully matured
Seed production	Avoid fields sown with pigeonpea in the previous season; keep at least 200 m away from fields sown with other cultivars of pigeonpea; remove all off-type plants before flowering
Seed storage	Sun dry seeds till moisture content is < 10%; clean the seeds and keep in new gunny bags; fumigate the store with Aluminum phosphate (Celphos) periodically

Seed production, storage and distribution

The seed system

Since there is no public and or private seed sector dealing with regular multiplication, maintaining the purity and trading of ESDP variety ICPL 88039 is a challenge. A few progressive farmers, who realized the potential of this genotype in rotation with wheat, took up its multiplication and distribution in the districts of Sonepat and Ghaziabad (Table 12). A total of 4.5 tons of seed of this genotype was sold during the 2004 rainy season and 7 to 8 tons during 2005 rainy season. It is estimated that this quantity of seed may have further increased the area of ICPL 88039 by 7000 ha in the NWPZ and central UP in 2006 rainy season. Approximately 80 tons of seed of ICPL 88039 was traded between farmers, farmers–traders and traders–small seed companies during the 2005 and 2006 rainy seasons (ML Jat Personal Communication). Increase in area ranged from neighboring villages where seed multiplication was initiated to distant villages, districts and states. For example RWC and ICRISAT purchased farmer-grown pure seed of ICPL 88039 for expansion of this variety in Rajasthan, eastern plain zones of India, Uttaranchal, Uttar Pradesh and Bihar in IGP.

Maintenance of the genetic purity of the ESDP variety ICPL 88039 was found to be the biggest constraint in the village level seed system. This is because village level agriculture extension workers and farmers are frequently ignorant of 30-40% out-crossing in pigeonpea. Most farmers sowed ESDP variety ICPL 88039 and UPAS 120 within close distance without maintaining the minimum isolation distance of at least 200 m that is required for pure-line seed production of pigeonpea.

Presence of long duration types

Indeterminate tall and long duration (maturity between 180-210 days) plants have always been recorded in plots of the indeterminate ICPL 88039. These long duration indeterminate type of plants were absent when fresh seeds of the test genotypes (ICPL 88039) from ICRISAT was sown; however, when seeds collected from such fields were sown in subsequent seasons, the number of long duration types of plants increased up to 40% in some farmers' fields. Such occurrences are attributed to 30-40% out-crossing in pigeonpea if a minimum isolation distance of 200 m is not maintained between two genotypes. These on-farm trials often have UPAS 120 and ICPL 88039 sown in the same field or within close distance of each other, at distances well below the recommended isolation distance.

Seed production

Availability of quality seed of improved cultivars is crucial for realizing maximum productivity and further expanding uptake of

Table 12. Seed multiplication, distribution and trade of ESDP genotype ICPL 88039 among farmers in districts of Sonepat, Ghaziabad, Mathura and Lalitpur[a]

District	Sold (kg)	Remarks
Sonepat	985	Sold to neighboring farmers and traders
Ghaziabad	10,610	Sold to neighboring farmers, seed companies and research organizations
Lalitpur	20,000	Sold to neighboring farmers
Mathura	10,000	Sold to farmers
Total	**41595**	Covered approximately additional area of 7000 ha during 2006

[a] Based on 2005 seed multiplication records.

such cultivars in different agro-climatic conditions. The quality of seed alone is known to account for at least 10-15% increase in productivity (ICAR 1993). However, lack of quality seed continues to be one of the greatest impediments in bridging the vast yield gap. Therefore, to approach the potentially realizable yield of a cultivar, production and distribution of quality seed is essential.

Good quality seed must necessarily have the following characteristics:

- Genetic purity, and uniformity; should conform to the standards of the particular cultivar;
- Disease-free, viable seeds;
- Free from admixtures of other crop seeds, weeds and inert matter;
- Acceptable uniformity with respect to size, shape and color.

Maintaining seed quality at farmers' level

A study conducted by the National Seed Project revealed that samples in most cases of farmer-saved seeds were sub-standard with respect to physical (15-100%) and genetic purity (37-80%), germinability (15-100%) and seed health (ICAR 1993). Also, farmers' seed samples gave 2 to 80% lower yield than certified seed in different crops. Considerable spread of released pigeonpea cultivars takes place through seed exchange among farmers, and therefore, care must be taken to avoid seed contamination with other cultivars due to out-crossing or mechanical mixing. Farmers should be educated to follow simple procedures to maintain seed purity at the farm level through leaflets, videos and seminars and meetings conducted by Krishi Vigyan Kendras (KVK) (centers for disseminating agricultural technology).

Pigeonpea, being a partially out-crossing crop, requires extra precautions to maintain varietal purity. Some important precautions that will help maintain purity and minimize seed contamination are listed here:

- Avoid delayed sowing for seed production as it may produce poor quality seed;
- Avoid fields that have been sown with pigeonpea in the previous season to avoid emergence of dormant seeds of the previous crop;
- Seed production plots of ESDP variety ICPL 88039 should be grown at least 200 m away from other cultivars of pigeonpea with an overlapping flowering phase to prevent out-crossing;
- Remove all off-type plants before flowering. Even among uniform looking plants, the late flowering plants should be removed to ensure that there is no drift of population towards later maturing plants;
- Prevent mechanical mixing and damage to seed. Care should be taken at the time of harvest to separate any off-type plants from the harvested bulk that might have been missed during roguing.

Seed storage

Considerable postharvest losses with pigeonpea occur during storage. The problem is more acute in the case of ESDP variety ICPL 88039 because the time between harvesting and next season's sowing is longer than for the other maturity groups. Many factors such as seed moisture, relative humidity, temperature and infestation by stored grain pests influence the viability of seed during storage and reduce the quality of seed. Seeds damaged by bruchids do not germinate well, resulting in poor plant stands and consequently low yields and economic loss. These factors force farmers to sell seed immediately after harvest even in cases where the market price may not be adequately remunerative.

Control measures

The following preventive and control measures are recommended to combat seed storage issues.

- Sun-dry the seed thoroughly before storage, because seed containing moisture > 10% tends to attract storage pests and is likely to be damaged soon. Seed can also be solarized for a couple of days before storing them in the shade. Seed kept in polythene bags and exposed to high temperatures (e" 65 °C) will kill insect pests. Storage in such bags makes chemical treatment unnecessary and seed can be stored for longer periods, safe for both sowing as well as consumption.
- Clean the seed store and remove old seed; do not store new seed with old seed.
- Prepare the floors and walls of stores well in advance by disinfecting with spray 1% Malathion (50 EC).
- Plug all cracks in the floor or walls of store to prevent entry of insects. Fumigate the store with Aluminum Phosphide (Celphos). While fumigating, take care to keep the stores or container airtight, as these chemicals are poisonous.
- Use new gunny bags lined with polythene to store seed. In case of old bags, disinfect them with 0.1% Malathion 50 EC or with Fenvelrate 20 EC. Dip old gunny bags in this solution for 10-15 minutes and dry properly in the shade before storing seed.
- Seed bags must be stored away from walls and they must not touch the floor. Bags should be placed on a thick layer of fine sand or cowdung ash as the layer acts as a repellent for insect pests.
- Grain earmarked for sowing should be mixed with 5% Malathion dust at 250 g/100 kg seed. Inspect the stored seed at regular intervals.
- For storage in seed bins (metal containers), disinfect the containers and place seed in them after proper drying. Spread a thick layer (2-3 inches) of dry coarse sand on top of the seed and close the lid properly.
- In case of insect attack, fumigate the seed in store with Aluminium Phosphide (30 g Celphos/t seed or 7-10 tablets of Celphos 28-m^{-3}). The exposure period should be one week for best results.
- Seed can also be treated with 7.5 ml rapeseed *(Brassica* spp.*)* oil or groundnut *(Arachis hypogea)* oil per kg of seed. This way, seed can be kept safe for as long as 8-9 months.

Future needs

Genetic improvement

Although considerable advantages of ESDP variety ICPL 88039 over SDP are evident in terms of higher yield of pigeonpea as well as of subsequent wheat, there is still a large gap between potential and realized yields by farmers. While this could partly be due to various biotic, abiotic and socioeconomic constraints, there could still be other unknown constraints that may be affecting the realization of high yield. Multidisciplinary research efforts are needed to improve yield and to adapt ESDP to target production systems to make its cultivation more competitive with rice or other rainy season crops. This list of researchable issues need to be addressed on priority basis:

- Breeding of appropriate plant type that includes characteristics such as rapid early growth, yield stability plant height (< 1 m) and increased harvest index under long photoperiod.
- Intensification of development of ESDP hybrids based on cytoplasmic male sterility.
- Breeding and selection of high yielding ESDP genotypes with multiple resistance/

tolerance for pod borers, *Phytophthora* blight *Fusarium* wilt and sterility mosaic diseases.

- Developing genotypes with adaptability to waterlogging and intermittent drought.

Crop production technology

The ESDP variety ICPL 88039, being a recent introduction in the rice–wheat cropping systems, requires:

- Development of a new, intensive intercropping system that can fit in ESDP as a component.
- Use of recently developed simulation models that can help resolve the complex management issues involved.
- Development of improved integrated pest management technologies for management of weeds, pests and diseases in ESDP ICPL 88039.

Transfer of improved technologies

Declining water tables and increased infestation of weed *(Phalaris minor)* in the rice–wheat system are a potential ecological threat. These points need early attention:

- Farmers' participatory research on ESDP should be given top priority by KVK and the state departments of agriculture. This can help create better focus on farmers' requirements of ESDP.
- Profitable and viable cropping systems involving pigeonpea (mixed, sequential and inter-crops) in different agro-climatic conditions must be identified.
- Concerted efforts must be made by agricultural extension staff to disseminate promising technologies to farmers through demonstrations, adaptation trials, and on-farm trials.
- Socioeconomic evaluation of technology must be done, along with testing for its appropriateness and acceptance by farmers.

Policy interventions

Policies and procedures that will aid seed production and maintenance of seed purity at farmers' level:

- Assured minimum support price to compete with cereals;
- Incentives to produce good quality seed;
- Development of processing units near production centers.

Summary and conclusions

The major objective of introducing ESDP variety ICPL 88039 in the IGP, in addition to increasing its production, was to improve the sustainability of the rice–wheat cropping systems. Since ICPL 88039 by itself requires little by way of purchased inputs and is known to improve soil fertility, it is ideally suited for cultivation in rotation with wheat. Salient features of its introduction into IGP are summarized (Figure 25) as follows:

The ESD pigeonpea variety ICPL 88039 grown in farmers' fields in IGP was found to be impressive; it gave higher yields than other cultivars such as Manak, Paras and UPAS 120.

- The variety matures 15-25 days earlier than any of the other pigeonpea cultivars (Manak, Paras and UPAS 120) grown in this region.
- It was found to be responsive to minimum life saving irrigation when sown during first week of May or earlier; was also found to be drought-tolerant when planted between the last week of May to the second week of June.
- There was no adverse effect on its yield from planting dates; although, the last week of May to mid-June planting was found to be the ideal time.
- Several villages in districts Sonepat (Haryana) and Ghaziabad (Uttar Pradesh) were found growing ICPL 88039 genotype of pigeonpea exclusively. It is also found suitable in the pigeonpea–wheat rotation in eastern IGP, central Uttar Pradesh and Madhya Pradesh.
- Pigeonpea genotype ICPL 88039 was found resistant to wilt disease and tolerant to pod borer. It was also found to be tolerant to intermittent drought.

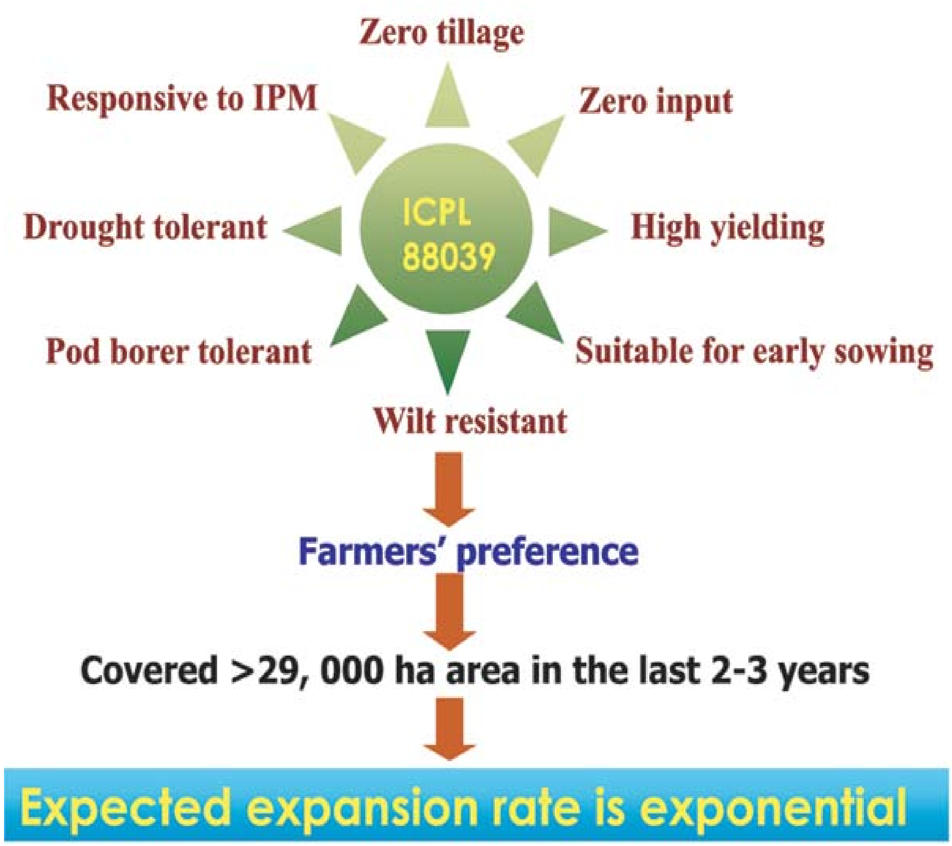

Figure 25. Salient features of ESDP variety ICPL 88039.

- Currently the expansion of the ESDP genotype ICPL 88039 from farmer to farmer is encouraging and > 25000 ha appear to have been covered by this genotype alone in the last 3-4 years. Its exponential expansion in eastern IGP, central Uttar Pradesh and Madhya Pradesh is encouraging.
- Non-availability of pure, quality seeds of ICPL 88039 is the main constraint to its spread.
- Also hampering the adoption and spread of ICPL 88039 and its improved technologies are weak linkages among research scientists, extension workers and seed agencies.
- There is need to further work out the agronomic optima for realizing the full yield potential of ICPL 88039 under a range of agro-ecological conditions in IGP.
- A comprehensive integrated pest management (IPM) system needs to be developed to control key pest and diseases and integrate it into crop production package.
- There is also an urgent need for developing location-specific production technology, gearing up of extension machinery for transfer of technology through large-scale demonstrations on farmers' fields and training of farmers to produce pure seeds of ICPL 88039.
- Also needed is assessment and evaluation of the scope of resource conservation technologies such as zero tillage and bed planting, including the use of permanent beds.
- The scope for introducing pigeonpea into various cropping systems such as pigeonpea–potato and pigeonpea late sown sugarcane in IGP also needs to be explored.

Observations of farmers' on-farm participatory demonstrations, and the increased adoption and expansion of ICPL 88039 have shown that it has scope and is an economical substitute for UPAS 120 and other pigeonpea genotypes grown by farmers in rotation with wheat in IGP-India. We strongly believe that popularization and further expansion of this variety and similar types would not only diversify rice–wheat rotation but will help conserve natural resources for the long term sustainability of the rice–wheat cropping system of IGP.

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About ICAR

The Indian Council of Agricultural Research has the Union Minister of Agriculture as its President. Its principal officer is the Director-General. He is also the Secretary to the Government of India in the Department of Agricultural Research and Education (DARE). The General Body, the supreme authority of the ICAR, is headed by the Minister of Agriculture, Government of India. Its members include the Minister of Agriculture, Animal Husbandry and Fisheries and senior officers of the various state governments, representatives of the Parliament, the agro-industries, scientific organizations and farmers.

ICAR acts as a repository of information and provides consultancy on agriculture, horticulture, resource management, animal sciences, agricultural engineering, fisheries, agricultural extension, agricultural education, home science and agricultural communication. It has the mandate to coordinate agricultural research and development programmes and develop linkages at national and international level with related organisations to enhance the quality of life of the farming community.

ICAR has established various research centers in order to meet the agricultural research and education needs of the country. It is actively pursuing human resource development in the field of agricultural sciences by setting up numerous agricultural universities spanning the entire country. The Technology Intervention Programmes also form an integral part of ICAR's agenda which establishes Krishi Vigyan Kendras (KVKs) responsible for training, research and demonstration of improved technologies.

About Rice–Wheat Consortium for the Indo-Gangetic Plains

The Consortium is an Eco-regional Program of the Consultative Group on International Agricultural Research (CGIAR) involving National Agricultural Research Systems, International Agricultural Research Centers, and Advanced Research Institutions. Its main objective is to promote research on issues that are fundamental to enhancing the productivity and sustainability of rice–wheat cropping systems in South Asia.

These objectives are achieved through:

- Setting priorities for focused research on problems affecting many farmers. Promoting linkages among rice–wheat research specialists and other branches of research and extension.
- Encouraging an interdisciplinary team approach to understand field problems and find solutions.
- Fostering quality work and excellence among scientists.
- Enhancing the transfer of improved technologies to farmers through established institutional linkages.

Financial support for the Consortium's research agenda currently comes from many sources, including the Governments of Australia, Netherlands, Sweden, Switzerland, and the Department for International Development (DFID), the International Fund for Agricultural Development (IFAD), the United States Agency for International Development (USAID), and the World Bank

About ICRISAT

The semi-arid tropics (SAT) encompasses parts of 48 developing countries, including most of India, parts of southeast Asia, a swathe across sub-Saharan Africa, much of southern and eastern Africa, and parts of Latin America. Many of these countries are among the poorest in the world. Approximately one-sixth of the world's population lives in the SAT, which is typified by unpredictable weather, limited and erratic rainfall and nutrient-poor soils.

ICRISAT's mandate crops are sorghum, pearl millet, finger millet, chickpea, pigeonpea and groundnut; these six crops are vital for the ever-increasing populations of the SAT. ICRISAT's mission is to conduct research which can lead to enhanced sustainable production of these crops and to improved management of the limited natural resources of the SAT. ICRISAT communicates information on technologies as they are developed through workshops, networks, training, library services, and publishing.

ICRISAT was established in 1972. It is one of 16 nonprofit, research and training centers funded through the Consultative Group on International Agricultural Research (CGIAR). The CGIAR is an informal association of approximately 50 public and private sector donors; it is co-sponsored by the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP) and the World Bank.

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* All other publications not listed here can be downloaded from the website : **www.rwc.cgiar.org**

Rice-Wheat Consortium for the Indo-Gangetic Plains

The Consortium is an Ecoregional Program of the Consultative Group on International Agricultural Research (CGIAR), managed by CIMMYT, involving the National Agricultural Research Systems, the International Agricultural Research Centers, and the Advanced Research Institutions. Its main objective is to promote research on issues that are fundamental to enhance the productivity and sustainability of rice-wheat cropping systems in South Asia.

These objectives are achieved through:

- Setting priorities for focused research on problems affecting many farmers.
- Promoting linkages among rice-wheat research specialists and other branches of research and extension.
- Encouraging interdisciplinary team approach to understand field problems and to find solutions.
- Fostering quality work and excellence among scientists.
- Enhancing the transfer of improved technologies to farmers through established institutional linkages.

Financial support for the Consortium's research agenda currently comes from many sources, including the Governments of Netherlands, New Zealand, Australia and the Department for International Development (DFID), the International Fund for Agricultural Development (IFAD), the United States Agency for International Development (USAID), the World Bank and the Asian Development Bank (ADB).

Rice Wheat

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