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# EXTRA-SHORT-DURATION PIGEONPEA FOR DIVERSIFYING WHEAT-BASED CROPPING SYSTEMS IN THE SUB-TROPICS

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## SUMMARY

The performance of newly developed extra-short-duration pigeonpea (*Cajanus cajan*) genotypes and traditional short-duration pigeonpea cultivars was compared in rotation with wheat in on-farm trials conducted in 1996–97 and 1997–98 in Sonepat (28° N) district in Haryana, and in 1996–97 at Ludhiana (30° N) district in Punjab, India. At both locations, a wheat crop (*Triticum aestivum* cv. HD 2329) followed pigeonpea. At Sonepat, an indeterminate extra-short-duration genotype ICPL 88039 matured up to three weeks earlier, yet gave 12% higher yield (1.57 t $ha^{-1}$) and showed less susceptibility to borer damage than did the short-duration cv. Manak. At Ludhiana, extra-short-duration pigeonpea genotypes, ICPL 88039, ICPL 85010 and AL 201 gave similar grain yields to the short-duration T 21 in spite of maturing three to four weeks earlier. Yields of wheat crops following extra-short-duration genotypes were up to 0.75 t $ha^{-1}$ greater at Sonepat and up to 1.0 t $ha^{-1}$ greater at Ludhiana. The results of the study provide empirical evidence that extra-short-duration pigeonpea genotypes could contribute to higher productivity of pigeonpea–wheat rotation systems. Most of the farmers who grew on-farm trials in Sonepat preferred extra-short-duration to short-duration pigeonpea types for their early maturity, bold seed size, and the greater yield of the following wheat crop.

## INTRODUCTION

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 $ha^{-1}$ and it occupies the field for 6 to 9 months. Crop improvement efforts in pigeonpea, as for other legumes (Siemonssma and Anwari, 1988; Lawn, 1989), have been directed both to improve yield of traditional types (Sharma *et al.*, 1981; Sheldrake and Narayanan, 1979; Willey *et al.*, 1981) and to develop new plant types that fit well into the new production systems (Wallis *et al.,* 1981; Laxman Singh *et al.*, 1990). 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 (Sharma *et al.*, 1981). These types are more suitable for subsistence agriculture with low plant density under mixed or intercropping situations (Willey *et al.,* 1981). Adoption of the short-duration (SD) pigeonpea genotypes developed in the 1960s and 1970s to substitute for long-duration genotypes has been limited due to their poor ability to fit into rotations with other crops such as wheat (*Triticum aestivum*) (Laxman Singh, 1996).

The ongoing intensification of agriculture, with a focus on multiple cropping to increase productivity, has necessitated the development of extra-short-duration (ESD) genotypes that can be grown as intensively as a monocrop (Wallis *et al.,* 1981; Laxman Singh, 1996). While these types have been found useful in terminal-drought environments (Nam *et al.,* 1993; Chauhan *et al.,* 1993; 1999), their usefulness in sequence cropping, such as the pigeonpea-wheat rotation for which they were initially developed, has not been assessed. For their acceptability in sequence cropping, these types need not only to be higher yielding than currently used varieties, but also to facilitate higher yield of following wheat or other winter crops grown in the post-rainy season. Compared with the SD pigeonpea cultivars that have been traditionally used in the pigeonpea–wheat rotation system, there is little information available on the on-farm performance of ESD genotypes, however. Such information is necessary to determine their acceptability to farmers and provide feedback on future research needs. Farmer participatory on-farm trials were organized, therefore, to evaluate ESD pigeonpea genotypes with respect to their reaction to pest damage, time to harvest maturity and yield potential when grown in rotation with wheat, while eliciting farmers' perceptions about them.

## MATERIALS AND METHODS

In the Sonepat district of the Indian State of Haryana, and about 40 km north of Delhi (28° N, 77° E), eight on-farm trials were conducted in 1996 and ten in 1997. In 1996, one such trial was conducted in the Ludhiana district (30° N 75° E) of Punjab. The soil in all the on-farm trial sites was sandy loam of >1 m depth with about 100 mm plant-available water $m^{-1}$ soil depth.

Soils of the Sonepat sites were neutral in reaction, non-saline, low in available N (79–84 mg $kg^{-1}$), medium in available P (3.5–4 mg $kg^{-1}$) and rich in K (167–175 mg $kg^{-1}$). Farmers were provided with seeds of genotypes ICPL 88039 (indeterminate, ESD), ICPL 85010 (determinate, ESD) and cv. Manak (indeterminate, SD). Together with some consultative input from scientists, farmers were responsible for identifying land, arranging genotypes within the experimental field, choosing sowing date and further managing of the on-farm trials. The farmers sub-divided their 0.4- to 0.6-ha experimental fields into two or three equal parts and the supplied genotypes were each assigned randomly to the plots. Each genotype plot thus measured 0.1 to 0.2 ha in different farmers' fields. Basal doses of 18 kg N and 20 kg P $ha^{-1}$ were applied to the fields before sowing. Pre-sowing irrigation was given for better field preparation and to ensure good establishment of the crop. This is a common practice for cultivation of SD pigeonpea in the region as irrigation facilities are widely available. Sowing dates of different on-farm trials ranged from 1 May to 18 June in 1996 and 8 May to 20 June in 1997. Seeds were sown in rows that were 40 cm apart giving a final stand of 10–12 plants $m^{-2}$. Previous on-station experience indicated that ESD and SD pigeonpea showed little increase in yield with increase in population from 8 to 60 plants $m^{-2}$ in this environment (Chauhan *et al.*, 1987). An individual trial site constituted a replication for a particular genotype. A single hand weeding was done about 30 d after sowing. To control pod borers such as *Helicoverpa armigera* and *Maruca vitrata*, ICPL 85010 was sprayed with endosulfan (0.4%) at the pod-initiation stage and with cypermethrin (0.004%) 10 d after the first spray. Blister beetle (*Mylabris pustulata*) attack at flowering was controlled by sprays of diclorvos (0.05%). ICPL 88039 and Manak could not be sprayed with insecticides as their plant heights were >2.5 m.

An on-farm trial was conducted at Ludhiana during 1996–97 on a sandy loam soil. Three ESD pigeonpea genotypes, namely ICPL 85010, ICPL 88039 and AL 201 (indeterminate), and an SD genotype, T 21 (indeterminate), were sown on 7 June 1996. There were two replications. The seeds were sown in rows spaced 50 cm apart and at a within-row spacing of about 25 cm, resulting in about 8 plants $m^{-2}$. The plot sizes were about 0.1 ha. The soil at this location was not analysed for initial fertility. The fields were kept weed-free manually, and no insecticide sprays were applied.

At both the locations, the standing crop of pigeonpea was irrigated 4–5 d before harvesting. This helped ease the removal of pigeonpea stubble and it also served as pre-sowing irrigation for wheat. The land was ploughed immediately after the pigeonpea crop was harvested. Within a fortnight of the pigeonpea harvest, and using a seed-cum-fertilizer drill, wheat (cv. HD 2329) was sown (125 kg $ha^{-1}$ in rows spaced 20 cm apart) along with the application of 40 kg N $ha^{-1}$ and 60 kg P $ha^{-1}$. An additional 80 kg N $ha^{-1}$ was applied in two equal doses with the first and second irrigations after sowing. The wheat crop at Sonepat was irrigated 24, 46, 65, 87, and 112 d after sowing, and at 22, 53, 72 and 108 d after sowing at Ludhiana. About 50 mm water was applied with each irrigation.

At Sonepat, crop duration, pod-borer damage, grain yields of pigeonpea and wheat (only in 1997–98) were recorded. Pigeonpea data for two seasons were pooled to identify superior genotypes. The standard errors of the means for different observations were computed for each genotype. To compute the relative response of different genotypes, the genotype mean yield was regressed against the on-farm trial's mean yield. In the on-farm trial at Ludhiana, crop duration, grain yield of pigeonpea and wheat were recorded. The standard errors of the means for different observations in the trial were calculated by analysis of variance.

At the end of the wet-season in 2000, smallholder (<3 ha) farmers (62 male and one female) who had grown ESD and SD pigeonpea at Sonepat during the preceding five years were interviewed to elicit their perceptions of ESD pigeonpea-wheat rotation *vis-à-vis* SD pigeonpea–wheat rotation. Spouses and other family members actively assisted in framing opinions about the fuel wood potential and taste of ESD pigeonpea.

Long-term weather data were obtained from the India Meteorological Department. For Ludhiana this covered the period 1952–82. In the absence of data for Sonepat, data for Delhi (1953–80) were considered relevant. A rainfall:potential evapotranspiration ratio (R:PE) (0.05 denotes the beginning of the rainy season and one <0.05 denotes its end). Soil water storage was calculated using the WATBAL water balance model of Keig and McAlpine (1974). The model uses the weekly inputs of rainfall, potential evapotranspiration and soil water storage capacity, and is not crop specific.

## RESULTS

The total annual rainfall at the Sonepat on-farm trial site was 976 mm in 1995, 771 mm in 1996 and 499 mm in 1997. At Ludhiana, the total rainfall was 827 mm. The long-term rainfall, R:PE and soil water storage for both the Delhi and Ludhiana environments presented a similar trend during the pigeonpea growing period (Fig. 1). The long-term rainfall average was 750 mm at Delhi and 850 mm for Ludhiana. The annual potential evapotranspiration was about 1660 mm for Delhi and 1360 mm for Ludhiana. The fourth week of June usually marks the commencement of the rainy season, as indicated by R:PE $\geqslant 0.5$, at both locations.

### *Sonepat on-farm trials*

The ESD genotype ICPL 88039 gave the highest mean yield of 1.57 t ha$^{-1}$ (Table 1). It was 16% more than ICPL 85010 and 12% more than Manak. The high yield of ICPL 88039 compared with that of Manak was achieved in spite of its earlier maturity by 19 d (Table 1). ICPL 85010, however, matured along with ICPL 88039 and yielded 3.7% less than Manak. The yield of pigeonpea genotypes increased linearly as the mean farm yield increased (Fig. 2). ICPL 88039 appeared to be about 20% more responsive to better production environments than Manak and ICPL 85010. On low-yielding farms, yield of ICPL 88039 was similar or marginally lower than the other two genotypes. Low yields were generally due to *Nilgai* (*Boselaphus tragocamelus*) damage, the effect of which was not quantified. There were large differences in pod borer damage among genotypes (Table 1) with the determinate and short-statured (<1.5 m tall) ICPL 85010 exhibiting the highest levels. In general, insecticides were not applied on ICPL 88039 and Manak because their height of more than 2.5 m made the spraying process too difficult.

The grain yield of wheat was increased by the preceding ESD genotypes (Table 1). It was highest after ICPL 88039, which was 0.75 t ha$^{-1}$ (19%) more than that after Manak and 0.2 t ha$^{-1}$ (4%) more than that after ICPL 85010. Wheat yield increased more after ICPL 85010 than after Manak even though the yield of ICPL 85010 was less than that of Manak. After Manak, wheat was sown in December.

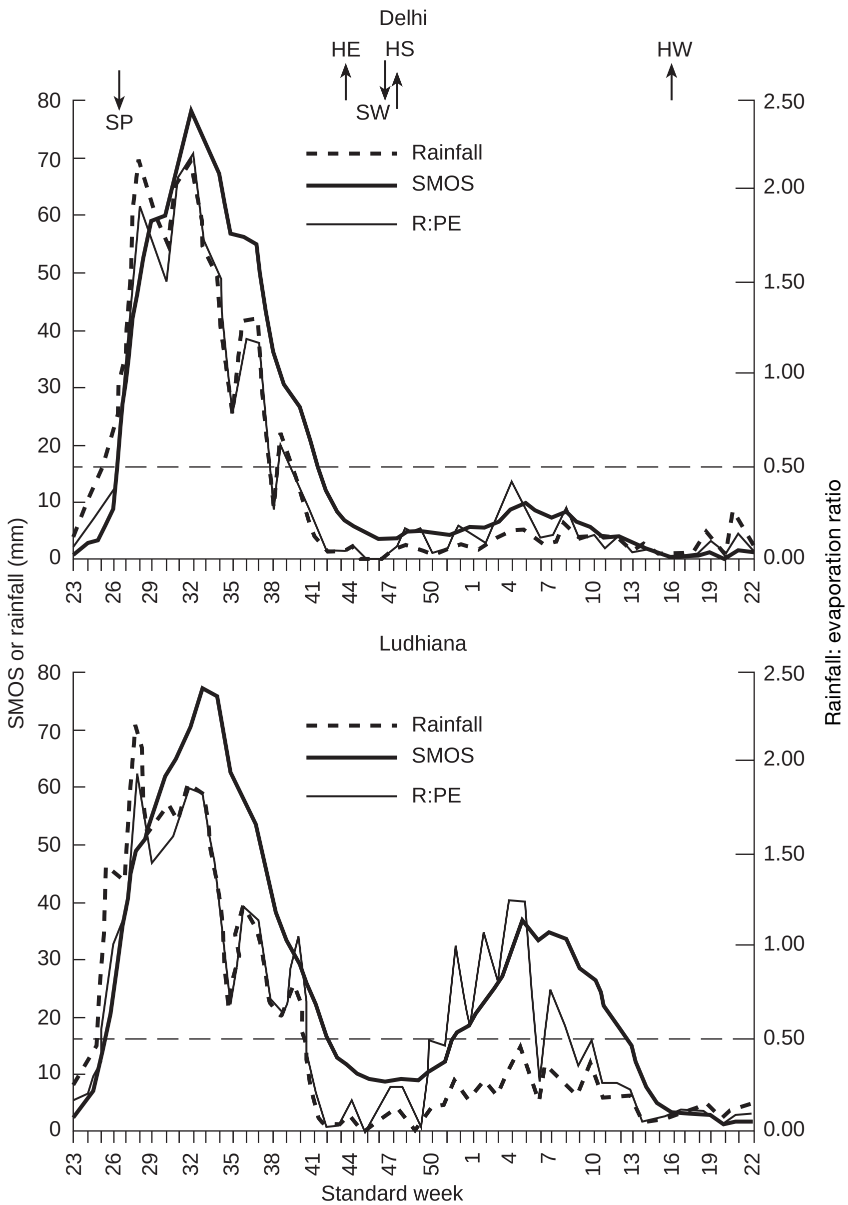


Fig. 1. Long-term rainfall, rainfall/potential evapotranspiration (R:PE) ratio and soil moisture storage (SMOS) of Delhi (near Sonepat) and Ludhiana environments. Generalized times of sowing of pigeonpea (SP), harvest of extra-short-duration pigeonpea (HE), harvest of short-duration pigeonpea (HS), sowing of wheat (SW) and harvesting of wheat (HW) are also shown by arrows.

*Ludhiana on-farm trial*

Grain yield of pigeonpea was similar among the genotypes tested (Table 2) and comparable to that obtained in Sonepat. Genotypes ICPL 88039, ICPL 85010 and AL 201 reached harvest maturity in 144 d, but T 21 matured in 170 d. Seed

Table 1. Mean days to harvest maturity, grain yield and pod-borer damage in two extra-short-duration genotypes and a short-duration pigeonpea cultivar in Sonepat, Haryana, rainy seasons 1996, 1997, and the performance of wheat following pigeonpea.

| | Pigeonpea | | | | Wheat† | |
|---|---|---|---|---|---|---|
| Genotype | No. obser-vations | Mean days to maturity | Grain yield (t ha$^{-1}$) | Pod borer damage (%) | Days to maturity | Grain yield (t ha$^{-1}$) |
| ICPL 85010 | 14 | 154 (3.6) | 1.35 (0.065) | 21.7 (3.95) | 142 (0.4) | 4.48 (0.088) |
| ICPL 88039 | 18 | 157 (3.8) | 1.57 (0.089) | 7.5 (3.17) | 142 (0.4) | 4.68 (0.066) |
| Manak (control) | 18 | 176 (2.9) | 1.40 (0.069) | 15.5 (3.13) | 133 (1.9) | 3.93 (0.076) |

Figures in parentheses are *s.e m.*

† Wheat yield was recorded in 1997–98 only and the mean was based on 9 observations. The grain yields (t ha$^{-1}$) in 1996 and 1997 were 1.28 and 1.48 for ICPL 85010, 1.42 and 1.65 for ICPL 88039 and 1.19 and 1.56 for Manak respectively.

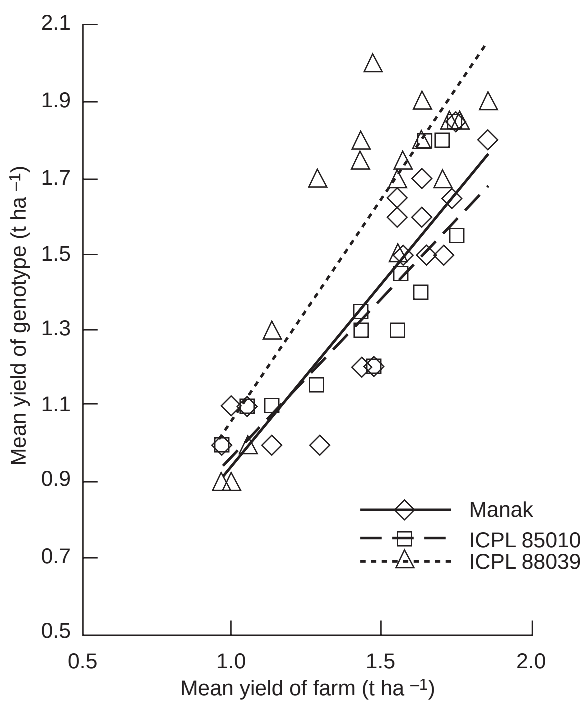


Fig. 2. Responsiveness of ICPL 88039, ICPL 85010 and Manak to different on-farm trial environments, Sonepat, 1996, 1997 rainy seasons.

For ICPL 85010 y = 0.150245 (+0.2218) ±0.829870 (±0.1513)** $r^2 = 0.72$

For ICPL 88039 y = (−0.100295 (±0.2283) +1.16823 (±0.1566)** $r^2 = 0.78$

For Manak y = (−0.013109 (±0. 0.1845) +0.962683 (±0.1239)** $r^2 = 0.78$

Table 2. Due to maturity, grain yield, and 100-seed mass of three extra-short-duration pigeonpea genotypes (ICPL 85010, ICPL 88039, and AL 201), a short-duration genotype (T 21) and of following wheat (cv. HD 2329) at Ludhiana, rainy season, 1996.

| Pigeonpea Genotype | Pigeonpea | | | Wheat yield ( t ha$^{-1}$) |
|---|---|---|---|---|
| | Days to maturity | Yield (t ha$^{-1}$) | Seed size (g 100-seeds$^{-1}$) | |
| 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 |
| T 21 | 170 | 1.66 | 6.8 | 3.86 |
| *s.e.* | 6.5 | 0.025 | 0.59 | 0.24 |

Table 3: Farmers perceptions about extra-short-duration pigeonpea as compared to short-duration pigeonpea, Sonepat, Haryana, 2000.

| Trait | Better | Similar | Poorer | Can't say |
|---|---|---|---|---|
| Yield | 53 | 47 | –[†] | – |
| Seed size | 98 | – | – | 2 |
| Price | 37 | 61 | – | – |
| Days to maturity | 78 | 20 | – | – |
| Pests | 87 | 7 | – | 5 |
| Fuel wood | – | 85 | 7 | 7 |
| Taste | 27 | 7 | – | 65 |
| Wheat crop | 77 | 8 | – | 15 |

[†] No respondent

size of ICPL 88039 was 30% greater than that of T 21. Wheat yield was up to 1 t ha$^{-1}$ lower after SD cultivar T 21 than that after the ESD genotypes.

*Farmers' perceptions*

Of the 63 farmers interviewed for their perceptions of ESD versus SDP in Sonepat District, 78% indicated that the early maturity of ESD was a major advantage. Some 87% suggested that pest incidence was lower in the indeterminate ESD and 77% indicated that they obtained higher wheat yield after ESD pigeonpea (Table 3). Only 53% indicated that ESDs have yield advantages over SD pigeonpea. Most of the 35% of farmers who consumed ESD pigeonpea preferred its taste to SD cultivars. Seventy five per cent of the farmers preferred indeterminate cultivars. 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 a more readily available and relatively cheaper fuel. They said that dried pigeonpea stems have excellent burning quality and produce less smoke than do other available fuel sources. A small percentage of farmers, however, indicated that stick yield from the ESD types was less than for the SD types. About 36% of the farmers interviewed in 1995 had grown SD pigeonpea and only about 17% had grown ESDs. In 1999, however, all these farmers had grown ESD types whereas only 15% of them had also grown SD, thereby indicating the increased preference and adoption of ESD over SD during this period.

## DISCUSSION

The results of the on-farm trials conducted in Sonepat and Ludhiana districts suggest that the reduced time to maturation of the ESD types did not cause reduction in yield as compared with the traditional SD types. Although a reduction in the duration of grain–legume growth period increases harvest index and enables it to escape from terminal drought stress, it is accompanied often by reduced yield and compensatory potential (Lawn, 1989). The growth periods of the ESD genotypes used in the present study, however, were longer than those of most short-season legumes and thus yields were not very low. Since ESD types are expected to be season-bound to facilitate sequence cropping with wheat, perhaps they do not require traits such as the greater phenological plasticity found in traditional types, which contributes to greater yield stability through strengthening their recovery mechanism. Such a trait is useful in the face of insect attack and drought, and for augmenting low first-harvest yield. It appears, however, that better tolerance to insect pest attack, as found in indeterminate ICPL 88039, would be required in the ESD pigeonpea background.

The ESD types require agronomic considerations for producing high yields different from those required for the traditional types. Traditional types are sown at the beginning of rainy season as mixed crops or inter-crops with fast growing cereals that smother weeds. In contrast, the ESD types would be mainly grown as mono-crops making them prone to greater weed competition. Most farmers, therefore, preferred to sow ESD types before the onset of rains, with pre-sowing irrigation. This helped to smother the weeds that sprouted with the onset of rains. Panwar and Yadav (1981) reported that early sowings resulted in greater stem yield of SD pigeonpea. The long-term soil water availability scenario indicated that, generally, soil water would not be limiting once the crop was established. Unless there is a protracted dry spell, further irrigation normally would not be required for the ESD types.

The plant population for obtaining a good yield from ESDs was about two to three times that required for traditional medium- or long-duration types. This means higher initial investment by farmers. A seed rate of 15 kg ha$^{-1}$ for ESD types, however, is still lower than those of other tropical legumes such as soyabean (*Glycine max*), mungbean (*Vigna radiata*), and black gram (*V. mungo*). Furthermore, where water is not limiting, it may be desirable to use higher plant densities to increase fuel wood production (Rao *et al.*, 1981). The ESD and SD pigeonpea types seem to have a broad optimum population in subtropical environments on account of high biomass production (Chauhan *et al.*, 1987). The higher yields from ESDs were realized at plant populations similar to those of the SD types.

An additional major gain apparently due to the introduction of these new plant types into the system was a 19% advantage in the yield of a wheat crop following an ESD type. Besides other factors, this gain could have been due to sowing in November. There was a delay of up to three weeks in the sowing date for the wheat crop after the SD Manak. After ESD genotypes, wheat can be sown from weeks 3–4 of November, which is optimum for the region. In Haryana, Ortiz-Monasterio *et al.* (1994) reported a linear decline in wheat yield of up to 0.8% $d^{-1}$ with delayed sowing beyond the optimum time. This nearly matches the decline of 0.75 t $ha^{-1}$ observed in the present study. The weight of fallen leaves was not recorded in this study. Another possible benefit of ESDs, however, may be that such leaves have a better chance of decomposing to provide mineral N to the following wheat because of their maturation during times of favorable temperatures.

At times, the extent of adoption of new varieties depends to a great extent on the perception and requirement of the women members of the family. A seemingly high-yielding pest-resistant improved cultivar of pigeonpea did not find favour with women farmers in the Medak district of Andhra Pradesh because it had poor taste (Pimbert and Women Sanghams, 1991). In the present study, most of the farmers preferred the new ESD types to the SD types for several traits including taste, seed quality and yield. The interviews with farmers revealed that shortage of fuel-wood was one of the major motivating factors for cultivation of pigeonpea. The availability of on-farm pigeonpea stems reduced the drudgery of fuel collection for the women and children usually deployed to carry out this task. Farmers also indicated that because pigeonpea stems produce less smoke and more heat, women valued its stems as fuel wood. In the wheat growing areas, farmers could not exploit the fuel wood potential of traditional and SD types because these do not fit in rotation with wheat. Even though some farmers felt that ESD pigeonpea produced slightly less fuel wood than did SD types, they preferred the former because they benefited the wheat, and increased the chances of including pigeonpea in the wheat-based system.

Wallis *et al.* (1981) and Lawn (1989) advocated the development of new types of legumes, including pigeonpea, to enhance yield potential and adaptation across latitudes and into new cropping systems. The results presented here support this. Therefore, the development of ESDs as new plant types provides a fresh opportunity to diversify intensive rice (*Oryza sativa*)–wheat systems. The new pigeonpea types could, however, have reduced the ability to compensate for lost leaf area or reproductive structures due to physical damage or environmental stress because of their short life cycle (Sharma *et al.*, 1981). Also, a large-scale introduction of new plant types could reduce biodiversity (Siemonsma and Anwari, 1988). The threat of pigeonpea biodiversity loss could be less serious with ESD types because greater adoption is expected in rice–wheat growing areas where traditional types cannot be grown due to their susceptibility to frost (Sharma *et al.,* 1981).

An alternative crop to rice in the Indo-Gangetic Plain region is required. This is because of declining water tables, increasing cost of rice cultivation and the need to address the broader question of sustainability of rice–wheat systems through crop diversification (Pingali and Shah, 1999). This study highlights their usefulness in intensive production systems *vis-à-vis* SD and other traditional cultivars that have been grown in the region so far. Although, currently available ESD types seem suitable to replace SDs in rotation with wheat, their yield seems less attractive to replace rice or other cereals. However, inputs required for ESD pigeonpea are also less. Further, improvements in the productivity of ESD types through agronomic or breeding efforts to give an average yield of 2 to 2.5 t $ha^{-1}$ would make this system more attractive for adoption in rice and wheat systems.

The ESD types may also be useful in other areas such as in eastern Africa, where pigeonpea is steadily gaining popularity (Silim and Tuwafe, 1996). Metho (1991) suggested that in some highland areas in Kenya where, after wheat is harvested, land is left fallow from August–September until March–April, cultivation of grain legumes such as pigeonpea and mungbean during the fallow phase would benefit farmers with additional food, cash and improved soil fertility. However, the initial attempts to include SD pigeonpea cultivars were not successful as they failed to produce any yield. Other grain legumes such as mungbean produced some yield. Perhaps the introduction of ESD pigeonpea in rotation with wheat would have been more successful. Indeed, Omanga *et al.* (1996) reported that some of the ESD genotypes gave yields as high as 3 t $ha^{-1}$ during the period October–March, suggesting that the potential of the new plant types of pigeonpea could be realized more widely.

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