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ADAPTATION OF EXTRA-SHORT-DURATION PIGEONPEA IN THE SHORT RAINY SEASON OF A TROPICAL BIMODAL RAINFALL ENVIRONMENT

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SUMMARY

The adaptation of extra-short-duration (ESD) and short-duration (SD) pigeonpea (*Cajanus cajan*) genotypes to the short rainy season (late March to late May; yala) was studied in Sri Lanka in 1995 and 1996. Eight ESD and two SD genotypes were sown on two dates in April and May, with and without supplementary irrigation. In addition, pigeonpea ESD genotype ICPL 88039, and SD genotype ICPL 86012, sesame (*Sesamum indicum* cv. M.I.3), blackgram (*Vigna mungo* cv. M.I.1) were compared under rainfed zero-tillage conditions after a rice crop at two locations in 1996. Grain yields of the pigeonpea genotypes under rainfed conditions ranged from 0.07 to 0.47 t ha^{-1} in the early sowings and 0.09 to 0.42 t ha^{-1} in the late sowings. The irrigated yields reached 1.7 t ha^{-1} in early sowing and 1.3 t ha^{-1} in the late sowings. Irrigation differentially influenced the performance of pigeonpea genotypes in both the sowings in 1996. Analysis of pooled data showed highly significant genotype × environment (year–sowing–irrigation combination) interactions. The interaction pattern among genotypes was associated with differences in the length of the reproductive period and the partitioning coefficient of genotypes. ICPL 88039, with the shortest reproductive period and one of the best in partitioning efficiency, recorded maximum mean yield. As a rainfed post-rice crop in farmers' fields, ICPL 88039 yielded 0.43–1.4 t ha^{-1} which exceeded yields of SD pigeonpea (0.02–0.88 t ha^{-1}), blackgram (0.03–1.00 t ha^{-1}) and sesame (0–0.09 t ha^{-1}). The results suggest scope for introducing ESD genotypes as a sole crop in the yala season in Sri Lanka since genotypes with short reproductive periods and high partitioning efficiencies are likely to have better adaptation to this season.

INTRODUCTION

The intensification of agriculture under rainfed conditions or with limited irrigation depends upon ensuring the optimum utilization of available soil water by the crops. Many tropical environments have characteristic bimodal rainfall patterns which offer the potential to increase cropping intensity. For example, an important characteristic of the rainfall of the dry zone of Sri Lanka spread over 4.17 million ha is its two well-defined rainy seasons – maha, the major rainy season from early October to late January and yala, the minor rainy season from late

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March to late May (Panabokke and Walgama, 1974). The mean rainfall (at Maha Illuppallama situated in the dry zone) during the maha season is about 800 mm and during the yala season 390 mm. The cumulative potential evaporation (513 mm) is much less than the precipitation in the maha season but it is much higher (530 mm) in the yala season. Drought is a major constraint for rainfed crops in the yala season, and crops such as sesame (*Sesamum indicum*), blackgram (*Vigna mungo*) and greengram (*Vigna radiata*) are cultivated to a limited extent. Very frequently, even these drought-escaping crops fail due to shortage of moisture. In addition, large areas under lowland rice are fallowed in the yala because of insufficient water in the reservoirs (both tanks and dams) to irrigate another rice crop. For enhancing cropping intensity in Sri Lanka, Panabokke and Walgama (1974) recommended choosing or breeding crops whose water demands fit closely with the probable moisture supply. They also suggested that the proper sowing date should constitute a central strategy for the optimum exploitation of rainfall. The crops could include drought-resistant short-duration (SD) legumes and cereals.

In Sri Lanka, identification of crops and cropping systems that would effectively utilize limited rainfall in the yala season has received considerable attention in recent years. In this context, attempts are being made to introduce SD pigeonpea in the maha season (Karunatilake *et al.*, 1996). One of the purposes of introducing pigeonpea in the maha season is to utilize the yala season for ratoon cropping of SD pigeonpea cultivars such as ICPL 87 (Karunatilake *et al.*, 1996). This can obviate the need to establish a crop under the erratic rainfall situation in the yala season. The crop in the maha season, however, is heavily attacked by the pod borers *Maruca vitrata* and *Helicoverpa armigera*, and its grain quality in certain seasons is affected by the extended end-of-season rains resulting in poor seed quality.

There is a possibility that pigeonpea could be grown in the yala season itself using extra-short-duration (ESD) cultivars. Extra-short-duration pigeonpea is a relatively new crop type developed for multiple cropping (Laxman Singh, 1996). Studies conducted by Chauhan *et al.* (1993) and Nam *et al.* (1993) suggested that ESD pigeonpea may have appreciable potential in short-growing-season environments. Identification of relatively drought resistant cultivars among ESD genotypes has further improved this prospect (Nam *et al.*, 1998). The potential of ESD pigeonpea in the yala season in Sri Lanka has, however, not been explored. The purpose of this investigation was to examine the adaptation of ESD pigeonpea to the yala season in the dry zone of Sri Lanka and to identify the physiological attributes that are likely to confer adaptation to this season.

MATERIALS AND METHODS

On-station experiment

The experiment was conducted at the Field Crops Research and Development Institute (FCRDI) farm, Maha Illuppallama, Sri Lanka. The soil of the experiment station is a Reddish Brown Earth that has low water-holding capacity and hardens quickly after rain. It is about 90 cm in depth and has a field capacity of 22%, wilting point moisture of 13%, and plant available moisture storage capacity of about 120 mm (Panabokke and Walgama, 1974). The chemical characteristics of the soil at the experimental site were pH 5.1 (s.e.m. 0.02), electrical conductivity (EC) 0.58 (0.024) dS m^{-1} (1 : 2 soil water extract), available phosphorus (P) 12.1 (0.06) mg kg^{-1} soil (Olsen and Sommers, 1982), total nitrogen (N) 1080 (12.5) mg kg^{-1} soil (Bremner, 1965), and organic carbon 0.76 (0.013)% (Nelson and Sommers, 1982). Two separate experiments were laid out in a split-plot design for two sowings on 3 April and 22 May 1995 and in an adjacent plot on 9 April and 9 May 1996. The main plots constituted contrasting water regimes, rainfed and irrigated at fortnightly (in 1995) or weekly (in 1996) intervals, and subplots were 10 genotypes, ICPL 87, ICPL 83015, ICPL 84023, ICPL 86012, ICPL 87111, ICPL 88007, ICPL 88032, ICPL 88039, ICPL 89002, and ICPL 89021. Of these, ICPL 87 and ICPL 86012 were SD genotypes and the others were ESD. Sowings were made on ridges spaced at 60 cm. Two paired rows spaced about 15 cm apart were sown on each side of the ridges. Plant-to-plant spacing within rows was 10 cm.

The crop in both sowings was established under rainfed conditions. In 1995, the irrigated treatment in the first (early) sowing was irrigated on 6 June and 21 June and the second (late) sowing on 14 June, 28 June, 13 July, 28 July and 12 August. In 1996, the crop was irrigated at weekly intervals starting from 7 May for the first sowing and 13 May for the second sowing except on 25 June and 10 July due to rainfall coinciding with these dates. The crop was hand-weeded when necessary and was given two or three insecticide sprays to control insect pests.

Days to 50% flowering (Df) and to 75% maturity (Dm) were recorded. At maturity for each sowing 4.56 m^2 area was harvested to record net plot yield, number of pods per plant, seeds per pod, 100-seed weight, and total dry matter (TDM) (excluding fallen plant parts). Yield was considered to be a function of three major physiological components: crop growth rate, duration of reproductive period and partitioning (Duncan *et al.*, 1978), which were calculated according to the following equations described by Chauhan *et al.* (1995):

$$C = TDM/Dm$$
$$Dr = (Dm - Df)$$
$$p = Y/(Dr \times C)$$

where Y = grain yield, Dr = length of reproductive period (d), C = crop growth rate (kg ha^{-1} d^{-1}) and p = partitioning coefficient.

Rainfall, temperature and evaporation were obtained from the nearby meteorological observatory. Soil moisture was calculated using the water balance model 'WATBAL' of Keig and McAlpine (1974).

On-farm trials

On-farm trials were sown on 23–24 April 1996 in farmers' fields at Kekirawa and Gallawa villages near Maha Illuppallama; these fields grew rice in the previous maha season. One of the sites represented a rainfed lowland rice situation (Gallawa) and the other (Kekirawa) a lowland rice situation under a major irrigation scheme. The chemical characteristics of the rainfed lowland site were pH 5.7, EC 0.07 dS m^{-1} (1:2 soil water extract), available (Olsen) phosphorus (P) 4 mg kg^{-1} soil, and organic carbon 1.98%, and of the lowland major irrigation site were pH 6.2, EC 0.09 dS m^{-1} (1:2 soil water extract), available P 23 mg kg^{-1} soil, and organic carbon 2.2%. No fertilizer was applied. Pigeonpea genotypes ICPL 88039 and ICPL 86012, blackgram (cv. M.I.1), and sesame (cv. M.I.3) were compared for yield and adaptation. The net plot size ranged from 15 to 26 m^2 and there were three replications on each site. Seeds were dibbled and grown further under zero-tillage rainfed conditions. There was no weed control and 2–3 insecticide sprays were applied to control insect pests.

Data analysis

The individual season data were analysed statistically using GENSTAT software (GENSTAT, 1983). Genotype × environment interactions were analysed using the additive main effect and multiplicative interaction (AMMI) statistical method consisting of combinations of year, irrigation and sowing date as an environment using the Rhizostatistics software of Cornell University (Zobel *et al.*, 1988). The purpose of the analysis was to quantify the multiplicative (G × E) interaction effects in yield and its physiological components and evaluate visually the genotype-by-environment interaction (GEI) pattern across the environments and environments and genotypes. The AMMI model for estimating Y_{ge} is $\mu + \alpha_g + \beta_e + \Sigma^N \lambda_n \xi_{gn} \eta_{en} + \theta_{ge}$, where Y_{ge} is yield of genotype g, in environment, e; μ is the grand mean; α_g is the genotype mean deviation; β_e is the environment mean deviation; λ_n is the eigenvalue of the interaction principal component axis (IPCA) n; ξ_{gn} and η_{en} are the genotype and environment scores for the IPCA axis n; θ_{ge} is residual and N is the number of IPCAs retained in the model. AMMI is a fully fixed effect model except for the error term. Therefore there is a single error term against which each component in an ANOVA is tested using Gollob's F-test (Gollob, 1968). The association of physiological components of yield was determined using correlation and regression analyses. For the on-farm trials means are presented with standard errors of mean values.

RESULTS

Weather

The total rainfall between standard weeks (SW) 13 and 35 was 495 mm in 1995 and 634 mm in 1996 (Fig. 1). The long-term average rainfall (1974–93) during this period is 450 mm. There was little rainfall between SW 19 and 35 in 1995 whereas appreciable rainfall occurred during this period in 1996, indicating the large variability in rainfall that can occur in the yala season. The maximum temperature during this period ranged from 30 to 35 °C and the minimum temperature from 20 to 25 °C. Soil moisture accumulation and depletion showed

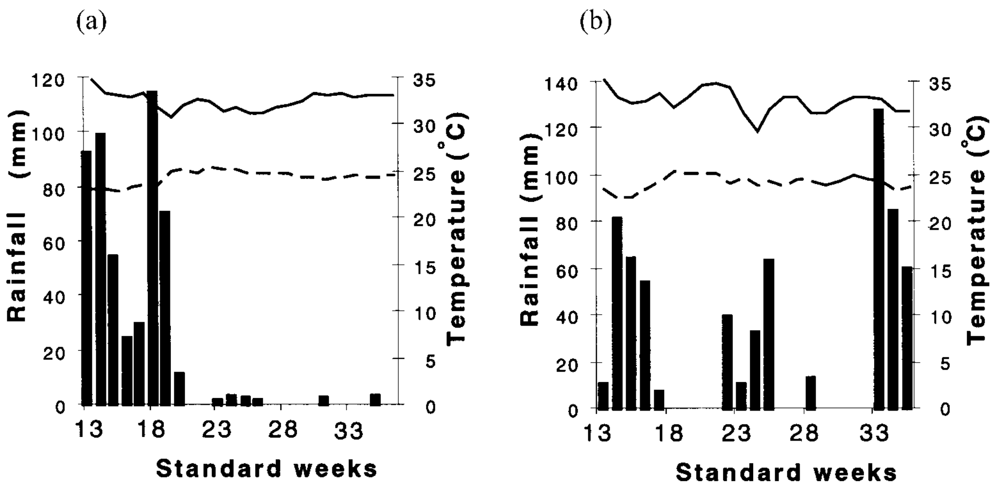


Fig. 1. Mean weekly minimum (– – –) and maximum (——) temperatures and rainfall in the (a) 1995 and (b) 1996 yala seasons at Maha Illuppallama.

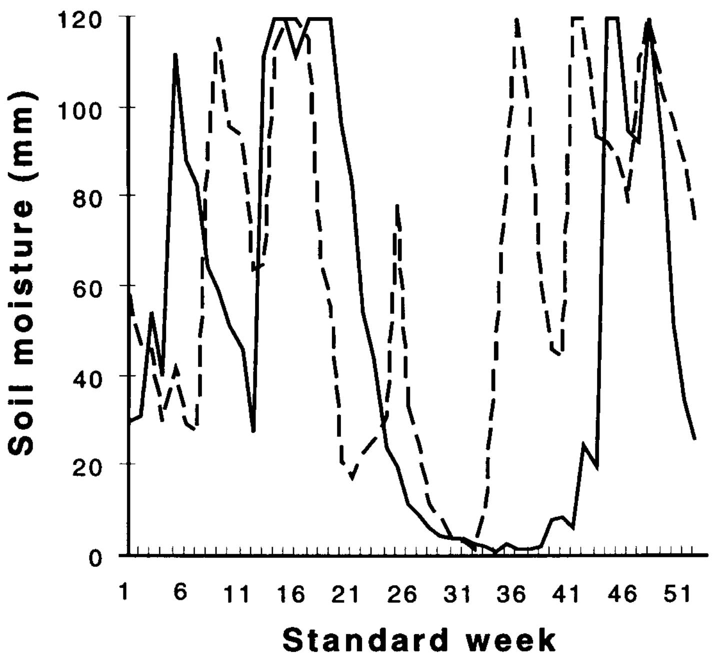


Fig. 2. Simulated soil moisture storage over standard weeks in 1995 (——) and 1996 (– – –) at Maha Illuppallama.

the same general trend in both 1995 and 1996 (Fig. 2). Soil moisture increased rapidly from SW 13 but declined equally rapidly around SW 18 to 21.

On-station experiments

Crop establishment. In each season both sowings were made under rainfed

Table 1. Plant stands (m^{-2}) of pigeonpea genotypes in early and late sowings in the yala season 1996 at Maha Illuppallama.

	Growth		Sowing date			
			9 April		9 May	
Genotype	Duration†	Habit‡	Rainfed	Irrigated	Rainfed	Irrigated
ICPL 87	SD	DT	20.1	20.4	13.1	13.3
ICPL 83015	ESD	DT	18.8	22.2	22.4	26.0
ICPL 84023	ESD	DT	22.5	20.1	19.1	24.3
ICPL 86012	SD	DT	10.2	11.0	9.1	14.0
ICPL 87111	ESD	IDT	4.3	5.1	8.5	12.3
ICPL 88007	ESD	DT	26.7	23.3	16.9	23.2
ICPL 88032	ESD	IDT	20.8	26.0	19.0	25.7
ICPL 88039	ESD	IDT	21.7	25.8	18.7	24.2
ICPL 89002	ESD	DT	18.8	24.6	22.9	25.5
ICPL 89021	ESD	IDT	14.0	12.2	5.0	7.9
Mean			17.8	19.1	15.5	19.6
s.e. irrigation × genotype			2.21 (1.77)§		2.68 (2.66)	
s.e. irrigation			1.44		0.90	

†ESD = extra-short-duration; SD = short duration; ‡DT = determinate; IDT = indeterminate; §s.e. values in parentheses are for comparing means at the same level of irrigation treatment.

conditions irrespective of the irrigation treatment. In 1995 establishment under rainfed conditions was satisfactory and 75–90% of the planned population (33 plants m^{-2}) was achieved (data not shown). However, plant stands of some genotypes were poor in 1996 (Table 1). In this season, plant stands averaged 57% in the irrigated and 55% in the rainfed treatments in the first sowing. In the second sowing the plant stand was 61% in the irrigated and 47% in the rainfed. In the first sowing plant stands of ICPLs 86012, 87111 and 89021 were significantly lower than those of ICPLs 87, 83015, 84023, 88007, 88032, 88039 and 89002. In the second sowing, plant stands of ICPLs 87, 86012, 87111 and 89021 were significantly lower than those of ICPLs 83015, 84023, 88007, 88032, 88039 and 89002. The interaction between soil moisture and genotype, however, was not significant.

Grain yield. Grain yields varied significantly between genotypes and irrigation treatments in both sowings within each year (Fig. 3). The irrigated yields were two to six times the rainfed yields. Grain yields under rainfed conditions ranged from 0.07 to 0.47 t ha^{-1} in the early sowings and from 0.09 to 0.42 t ha^{-1} in the late sowings. The irrigated yields reached 1.7 t ha^{-1} in early sowings and 1.3 t ha^{-1} in the late sowings. In 1995 ICPL 87, ICPL 84023, ICPL 86012, ICPL 87111, ICPL 88007, ICPL 88032 and ICPL 88039 gave significantly higher yields than ICPL 83015, ICPL 89002 and ICPL 89021 (Fig. 3). In the second sowing ICPL 88039 and ICPL 83015 gave significantly higher mean yields than

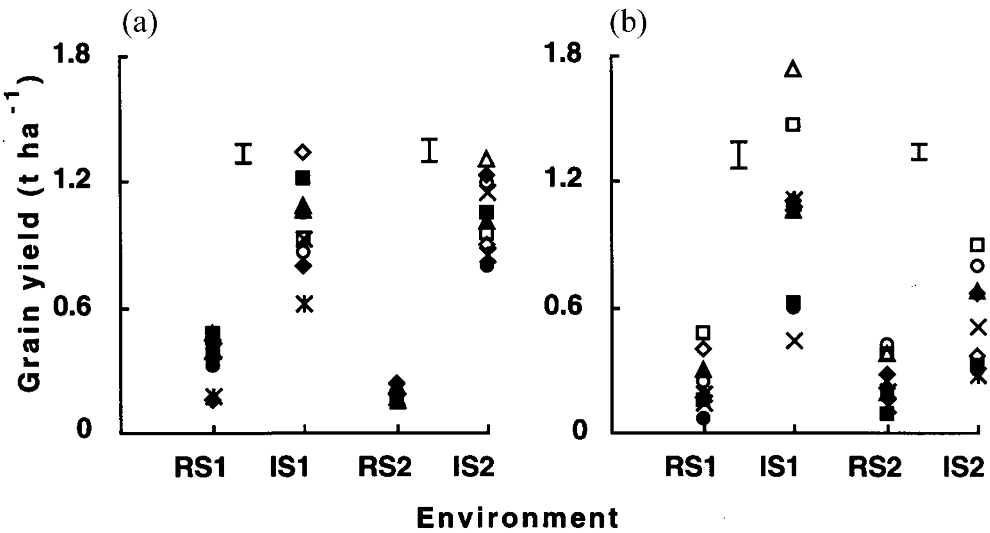


Fig. 3. Grain yield (t ha^{-1}) of pigeonpea genotypes (■ ICPL 87; ◆ ICPL 83015; ▲ ICPL 84023; ● ICPL 86012; ✕ ICPL 87111; □ ICPL 88007; ◇ ICPL 88032; △ ICPL 88039; ○ ICPL 89002; ✱ ICPL 89021) in early and late sowings in the yala seasons of (a) 1995 and (b) 1996 at Maha Illuppallama. The bars are standard errors of the means to compare genotypes within an adjacent irrigated or rainfed treatment. Codes for environments are I = irrigated, R = rainfed, S1 = early sowing, S2 = late sowing.

ICPL 87, ICPL 84023, ICPL 86012, ICPL 88007, ICPL 88032 and ICPL 89021. The genotype × irrigation treatment interaction was not significant for either of the sowings of 1995.

In 1996, genotype × irrigation treatment interactions were highly significant for both the sowings (Fig. 3). In the first sowing ICPL 88039 significantly outyielded every other genotype in the irrigated conditions whereas genotypes did not differ significantly in the rainfed treatments. In the second sowing ICPL 89002 was the highest yielding genotype in the rainfed treatments but did not differ significantly from ICPL 88039 and ICPL 88007. In the irrigated treatment ICPL 88007 recorded the highest yield. The overall mean grain yield in the rainfed treatments was 28% of that in the irrigated treatments.

Genotype × environment interaction for yield. The genotype × environment interaction (GEI) was analysed using the AMMI statistical model which extends the ANOVA analysis by applying principal component analysis to the ANOVA interaction effects. The main effects of environments (each environment being a combination of year, sowing date and irrigation) and genotypes were highly significant (Table 2). The GEI was also highly significant (Table 2). Genotypes accounted for 8%, environments 78%, and GEI 14% of variation in total sums of squares. AMMI analysis partitioned the interaction effects into three significant interaction principal component axes (IPCA). Of the 14% of the total variation accounted by GEI, 50% was accounted for by the first significant interaction principal component axis (IPCA 1), 32% by the IPCA 2 and 11% by the IPCA 3.

Table 2. ANOVA for additive main effect and multiplicative interaction (AMMI) analysis of genotype and environment interactions.

Source	d.f.	Sums of squares	% sums of squares	Probability
Treatment	79	38.7	88	***
Genotype (G)	9	3.2	8	***
Environment (E)	7	30.2	78	***
G × E	63	5.3	14	***
IPCA 1	8	2.6	50	***
IPCA 2	8	1.7	32	***
IPCA 3	8	0.6	11	*
Residual	39	0.4		
Error	157	5.5		
Total	236	44.2		

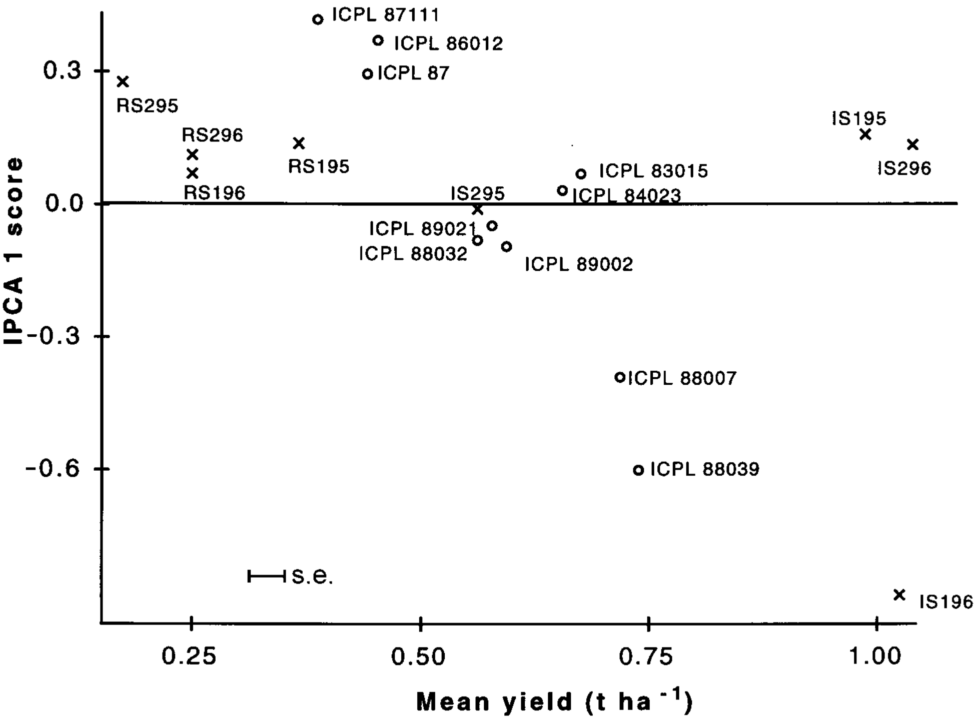
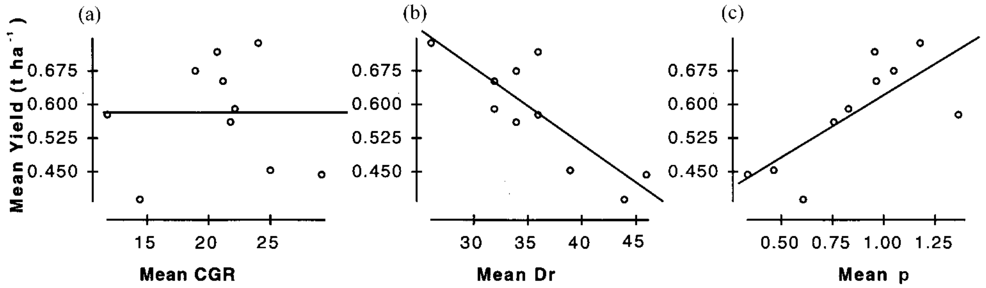


Fig. 4. Biplot of the relationship between interaction principal component axis 1 (IPCA1) score and mean yields of genotypes (o) and environments (×). Codes for environments are I = irrigated, R = rainfed, S1 = early sowing, S2 = late sowing, 95 = 1995 season, 96 = 1996 season, s.e. = standard error of the mean.

The biplot between the IPCA 1, which accounted for the largest (50%) variation in GEI, and mean yield provided a visual pattern of the interaction (Fig. 4). A comparison of spread of genotypes and environments along the x-axis indicates variation in mean yield of genotypes and environment. The range of variation in yield across environments was greater than that for genotypes. Mean grain yield



y = 1.20 − 0.17 Dr; r^2 = 0.71 y = 0.34 + 0.28 p; r^2 = 0.56

Fig. 5. Relationship between the mean yields of 10 genotypes and (a) crop growth rate (CGR), (b) duration of reproductive period (Dr) and (c) partitioning (p).

was highest in ICPL 88039 and lowest in ICPL 87111. The distance among the genotypes and environments along the y-axis provides the indication of interaction pattern. An environment and genotype combination with IPCA 1 scores of like sign has a positive interaction which results in more yield while a combination with opposite signs has a negative interaction which results in decrease in yield. Genotypes ICPL 87111, ICPL 87 and ICPL 86012 had the opposite interaction pattern to ICPL 88007 and ICPL 88039. This also indicated that as the realized mean yield increased the IPCA 1 scores of genotypes also changed. In contrast IPCA 1 scores of all the environments except one (irrigated first sowing in the 1996 season) were close to zero and showed no systematic change in pattern.

Relationship between yield and physiological traits. Grain yields across genotypes were negatively correlated with time to maturity (r = −0.833**), but not with dry matter (r = −0.241) or time to flowering (r = −0.201). Grain yields of genotypes were independent of crop growth rates, but increased linearly with improvement in partitioning efficiency and decreased linearly with increase in duration of reproductive period (Fig. 5). The IPCA 1 scores were significantly correlated with the time to maturity (r = 0.78**) and the length of the reproductive period (r = 0.80**). Across environments, however, grain yields had a significant positive correlation with crop growth rates (r = 0.86**), and partitioning coefficients (r = 0.82**) but had no association with the length of the reproductive period.

Grain yield components. Hundred-seed mass and numbers of seeds per pod were not significantly greater in the irrigated treatments than in the rainfed treatments (Table 3). The numbers of pods per plant were significantly reduced in the rainfed treatment.

On-farm trial

Comparison among crops. In the on-farm trial comparing different crops ICPL 88039 was highest yielding at both Gallawa and Kakirawa (Table 4). The

Table 3. Effect of irrigation on yield components of pigeonpea genotypes sown on 9 April in the yala season 1996 at Maha Illuppallama.

	Seeds per pod		100-seed mass		Pods per plant	
Genotype†	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated
ICPL 87	0.9	2.1	10.1	11.5	37	79
ICPL 83015	1.6	2.4	9.5	8.7	23	53
ICPL 84023	2.1	2.0	9.2	8.7	32	61
ICPL 86012	1.1	2.2	10.6	13.4	30	68
ICPL 87111	1.8	2.2	6.2	8.1	28	101
ICPL 88007	2.7	2.4	10.0	10.0	26	63
ICPL 88032	2.3	2.2	10.1	9.6	29	56
ICPL 88039	2.4	2.8	9.9	9.9	30	60
ICPL 89002	1.6	2.1	9.0	9.5	35	69
ICPL 89021	2.4	2.1	10.5	10.4	23	51
Mean	1.9	2.3	9.5	10.0	29	66
s.e. (irrigation)	0.25		0.29		3.6	
s.e. (genotype × irrigation)‡	0.49		0.74		9.1	

†Growth habit and duration are indicated in Table 1; ‡standard error of mean for comparing means within a treatment.

Table 4. Grain yields (t ha^{-1}) of pigeonpea, blackgram and sesame crops in rice fallows in the yala season 1996 at Kekirawa and Gallawa near Maha Illuppallama.

		Grain yield	
Crop	Genotype	Kekirawa	Gallawa
Pigeonpea	ICPL 88039	1.39 (0.68)†	0.43 (0.057)
	ICPL 86012	0.88 (0.280)	0.02 (0.005)
Blackgram	MI 1	1.00 (0.003)	0.03 (0.007)
Sesame	MI 3	0.09 (0.226)	0.00 (failed)

†Standard errors of the mean are in parentheses.

advantage of ICPL 88039 was even greater at Gallawa where only ICPL 88039 gave some yield whereas ICPL 86012 and the sesame and blackgram crops failed.

DISCUSSION

The yala season in Sri Lanka is characterized by sunshine and temperatures conducive to the growth of tropical crops, but rainfall is low and erratic, especially in the dry zone. Therefore fields are either fallowed or cropped with very early maturing crops which give low yields. Large responses to irrigation in pigeonpea yield (across sowing dates and seasons) suggest that moisture is indeed a limiting factor for yield in this season even when rainfall is slightly above the long-term average.

The sowing date in the yala season is likely to fluctuate depending on the onset of rains. The results of this study demonstrated that it is possible to establish a pigeonpea crop under rainfed conditions in the yala season itself. There appear to be genetic differences in establishment and survival which were very evident in 1996 when a large gap in rainfall occurred during the second sowing and some genotypes had poor stands. Insufficient moisture availability in the seed zone and later mortality induced by drought appeared to be major factors responsible for the poor stand of pigeonpea. ICPLs 88007, 88039, 88032 and 89002 had better stand establishment than others irrespective of sowing time. Thus, such genotypes may impart greater flexibility in sowing time. However, for optimum utilization of rainfall it would be desirable to sow at the onset of rains, especially under rainfed conditions. In the present study, late sowings reduced both rainfed yields and the irrigated yields in 1996.

Grain yields under rainfed conditions reached 0.48 t ha^{-1} in the on-station trials and 1.4 t ha^{-1} in on-farm trials. The rainfed yields are comparable to those generally obtained in the tropical parts of India in the rainy season. Greater realization of yields in the on-farm trial under zero tillage conditions at the lowland major irrigation site could be due to trapping of rain water by field bunds. Such yields could also be realized with irrigation. Limited irrigation is available under the various irrigation schemes in some areas in Sri Lanka, but water from the irrigation schemes is not sufficient to cultivate two rice crops a year and so a substantial area is kept fallow during the yala season (Dimantha, 1987).

In the on-station experiments in the first season and in the on-farm trials, ICPL 88039 gave the highest mean yield. Its performance in the irrigated treatments suggest that it could be an appropriate genotype for situations with variable moisture availability. It also possesses greater resistance to drought and *Helicoverpa* pod borer (Y. S. Chauhan, C. Johansen, T. G. Shanower and Laxman Singh, unpublished results), factors which could become a major production constraint in the yala season.

The variation in the performance of genotypes across environments is a combination of genotype main effect and GEI, environment main effects being common to all genotypes. The genotype and GEI effects are therefore of immense importance to plant breeders and agronomists as appropriate exploitation of these effects can result in optimizing yield in a given environment. The AMMI analysis indicated that GEI accounted for twice as much variation in yield as the genotype main effect signifying its importance. Mean yields of genotypes varied significantly. ICPL 88039 was the highest yielding genotype. Within the narrow range of maturity of the ESD and SD genotypes, yields declined with increasing maturity duration. This confirms the superiority of earlier maturing genotypes in short growing seasons (Chauhan *et al.*, 1993). Phenological variation even seems to contribute to GEI as was evident from the significant association of length of reproductive period and time to maturity with IPCA 1. Thus, the IPCA 1 score distribution was interpretable in terms of time to maturity and the length of reproductive period. Three groups of genotypes were apparent on the basis of

IPCA 1 scores. Those with high yields and high IPCA 1 scores comprised the two ESD genotypes ICPL 88039 and ICPL 88007. The other group comprising ICPL 88011, ICPL 86012 and ICPL 87 had low yields and high IPCA 1 scores of opposite sign compared with ICPL 88039 and ICPL 88007. These were later maturing and had low mean yields. The third group with intermediate yield levels had close to zero IPCA 1 scores. The genotypes with IPCA 1 scores close to zero may produce stable yields across moisture or sowing date environments but would not optimize yield in a given environment. For obtaining high yields, genotypes such as ICPL 88039 and ICPL 88007 with high mean yields and high IPCA 1 scores may do well. Such genotypes may do reasonably well in environments with close to zero IPCA scores and may do exceptionally well in environments with high IPCA scores of like sign such as the irrigated first sowing in 1996.

In addition to a short reproductive period, the ability of a cultivar to remobilize stored assimilates confers an adaptive advantage in several crops, especially in terminal drought situations (Subbarao *et al.*, 1995). A partitioning coefficient of >1 suggests remobilization of stored assimilates for pod production and filling in addition to the use of current assimilates. In pigeonpea, the ability to remobilize assimilate from stems to pods appears to be a major limitation for SD genotypes such as ICPL 87 (Lopez *et al.*, 1994). In this study dry matter partitioning was particularly low in the SD cultivars ICPL 87 and ICPL 86012. Greater remobilization of assimilates could also be a factor responsible for the short reproductive periods of genotypes with higher partitioning coefficients. Indeed there was a significant correlation between reproductive duration and the partitioning coefficient. ICPL 88039 had the shortest reproductive period and the greatest mean yield. Crop growth rate, however, was not associated with yield across genotypes but was related yield across environments. This suggests that agronomic factors that can contribute to higher total dry matter production in conjunction with genotypes with higher partitioning coefficients and short reproductive periods may ensure higher yields in the yala season.

Decrease in grain yield in the late sowing was due to a significant reduction in number of pods per plant. While low seeds per pod and pods per plant may contribute primarily to lower seed yield, low seed mass reduces the dhal (decorticated split seed) quality in addition to yield. This suggests that variable moisture supply may not affect the quality of produce in the yala season, although the total yield may be reduced by drought.

The results of the study demonstrate that it is possible to grow pigeonpea in the yala season and, with appropriate adjustments in planting time and moisture conservation techniques such as bunding in rice fields, economic yield levels (>0.5 t ha^{-1}) can be realized which at US\$0.40 kg^{-1} seed can fetch a net profit of $>$ US\$ 200 ha^{-1}. A farmer recorded a profit of up to about US\$1000 ha^{-1} from a yala season crop following a rice crop (Saxena, 1998). While the production costs are not very different for blackgram or sesame that are commonly grown in this season, the profits are likely to be much less due to much lower yields. The prices of blackgram and other pulse crops grown in the country are similar to pigeonpea, but that of sesame is generally higher. A better feature of the yala season is that, in spite of the inadequacy of rainfall to match the evapotranspirational demand of the crop, it is relatively free from the crop damage caused by excess rainfall that frequently occurs in the maha season (Panabokke and Walgama, 1974). Further, the residual soil moisture reserves from the preceding maha season (from rain as well as irrigation to the rice crop), which could be as high as 120 mm in a 90 cm soil profile, could help to alleviate the moisture deficiency in the event of inadequate rainfall. Currently, this moisture is largely utilized by weeds. The availability of ESD pigeonpea has opened up the possibility of utilizing the limited water in about 280 000 ha of potential land that exists in the rice fallows alone. The study also established that significant variation in the yield of different genotypes can be attributed to specific traits such as short maturity period, short reproductive period and greater partitioning efficiency.

Recent surveys suggest that pigeonpea is acceptable to Sri Lankan consumers and farmers (Saxena, 1998). As in the present study, several instances of successful pigeonpea crops have been reported where a soyabean or maize crop failed due to drought. However, to translate this into an enhanced income for farmers, effective marketing channels have yet to be developed. This, together with the large-scale availability of quality seed for sowing, will need to be addressed urgently if pigeonpea is to become a major crop in Sri Lanka. Some progress has already been reported on these aspects (Saxena, 1998).

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