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Factors affecting growth and yield of short-duration pigeonpea and its potential for multiple harvests

By Y. S. CHAUHAN, N. VENKATARATNAM and A. R. SHELDRAKE*

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru P.O. Andhra Pradesh 502324, India

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SUMMARY

Environmental and cultural factors that may limit the yield of short-duration pigeonpea were investigated over three seasons. Plants in the peninsular Indian environment at Patancheru grew less and produced less dry matter by first-flush maturity than at Hisar, a location in northern India where the environment is considered favourable for the growth of short-duration pigeonpea. However, with a similar sowing date in June, the mean seed yields of three genotypes, ICPL 4, ICPL 81 and ICPL 87, were very similar, at about 2·3 t/ha, in both environments. This was mainly due to the higher ratio of grain to above-ground dry matter at Patancheru. In addition to the first harvest, all genotypes showed a potential for two more harvests owing to the warm winters at Patancheru. The potential for multiple harvests was particularly high in ICPL 87, which yielded 5·2 t/ha from three harvests in 1982–3, 3·6 t/ha from two harvests in 1983–4, and 4·1 t/ha from three harvests in 1984–5. The optimum plant population density at Patancheru was 25–35 plants/m^2 for ICPL 87, but was higher for the other two genotypes.

At Patancheru, the total dry-matter and seed yield of first and subsequent harvests were significantly reduced by delaying sowing beyond June. Generally, the second- and the third-harvest yields were lower on vertisol than on alfisol under both irrigated and unirrigated conditions.

The total yield of ICPL 87 from two harvests was far higher than that of a well-adapted medium-duration genotype BDN 1, grown over a similar period. The yield advantage was greater on the alfisol because of the better multiple harvest potential of this soil. The results of this study demonstrate that properly managed short-duration genotypes of pigeonpea may have considerable potential for increased yield from multiple harvests in environments where winters are warm enough to permit continued growth.

INTRODUCTION

In India, pigeonpea of about 6–9 months' duration has traditionally been grown as an intercrop. However, during the last decade it has been shown that genotypes of shorter duration, i.e. of about 4–5 months, when sown alone at the normal sowing time can give yields similar to or even higher than long-duration genotypes in northern India (Saxena & Yadav, 1975). Wallis *et al.* (1983) have also shown in Queensland, Australia, that properly managed short-duration and photo-insensitive genotypes of pigeonpea can produce yields of up to 8·8 t/ha, and that a ratoon crop can also be harvested. Thus by adopting pigeonpea of shorter duration, it appeared possible not only to increase the production of this pulse crop but also to create a greater flexibility in its use, which so far has been limited mainly to intercropping (Willey, Rao & Natarajan, 1981).

Sole cropping of short-duration pigeonpea is already becoming popular in northern India, where it can be followed by a wheat crop (Kanwar, 1981). It was previously thought that short-duration pigeonpea was not suitable for peninsular India (Green *et al.* 1981), so research on pigeonpea in this environment has been limited mostly to medium- and long-duration types. There has been little attempt to identify the factors that limit the adaptation of short-duration pigeonpea. Such information would help to exploit its potential fully. The present investigations were, therefore, undertaken with the following objectives: (*a*) to determine the

* Present address: 20 Willow Road, London NW3, England.

Table 1. *Details of experiments conducted in the* 1982–3, 1983–4, *and* 1984–5 *seasons*

Soil	Date of sowing	Treatments†	Design replications	Plot size (m)	Irrigation (days after sowing)*
		1982–3 season			
Alfisol	15 June	Genotype: ICPL 4, ICPL 81, ICPL 87; Spacing (cm): 50 × 20, 37·5 × 10, 30 × 8, 25 × 6	RBD, 3	6 × 4	17, 69, 122, 157, 182, 220
Alfisol	23 Aug.	Genotype: ICPL 4, ICPL 81, ICPL 87; Spacing (cm): 50 × 20, 37·5 × 10, 30 × 8, 25 × 6	RBD, 3	6 × 4	0, 53, 88, 133, 151
Entisol	15 June	Genotype: ICPL 4, ICPL 81, ICPL 87; Spacing (cm): 50 × 20, 37·5 × 10, 30 × 8, 25 × 6	RBD, 2	6 × 4	8, 79, 100
		1983–4 season			
Alfisol	23 June	Genotype (SP): ICPL 4, ICPL 81, ICPL 87; Spacing (cm) (SP): 50 × 10, 37·5 × 7·5, 30 × 6; Irrigation (MP): Irrigation, no irrigation	Split-plot, 3	6 × 4	140, 180, 211
Vertisol		Genotype (SP): ICPL 81, ICPL 87; Spacing (cm) (SP): 50 × 10, 37·5 × 7·5, 30 × 6; Dates of sowing (MP): 28 June, 27 July, 22 Aug.	Split-plot, 3	6 × 4	
		1984–5 season			
Alfisol		Dates of sowing (SP): 11 June, 25 June, 10 July, 25 July	Split-plot, 3	6 × 4	0, 74, 142, 219, 255
Vertisol using ICPL 87		Irrigation (MP): Irrigation, no irrigation			0, 82, 151, 220, 256
Alfisol	15 June	Genotype: ICPL 87, BDN 1	RBD, 3	9 × 6	0, 70, 138
Vertisol					0, 78, 147

Except for the experiment on entisol at Hisar all experiments were conducted at Patancheru.
* Calculated from first sowing date.
† SP, subplot; MP, main plot.
‡ RBD, randomized-block design.

effect of location, soil type, and sowing date on the performance of short-duration pigeonpea, (*b*) to study effects of plant population density, and (*c*) to compare the performance of short-duration genotypes with a medium-duration genotype grown under near-optimum conditions to determine the potential of growing short-duration pigeonpea in peninsular India.

MATERIALS AND METHODS

Experiments were carried out in the three seasons of 1982–3, 1983–4 and 1984–5. In the first season, experiments were conducted at two locations in India, on an alfisol (Udic Rhodustalf) at International Crops Research Institute for the Semi-arid Tropics (ICRISAT) Center, Patancheru (17° N 78° E, 545 m elevation), and on an entisol (Typic Camborthids) at Hisar (29° N 75° E, 221 m elevation). In the other two seasons, experiments were conducted at ICRISAT Center, Patancheru, on an alfisol and a vertisol (Typic Pellustert). The alfisol may hold less than 100 mm of available water, the entisol about 200 mm and the vertisol about 250 mm in the rooting zone. A basal dose of 100 kg/ha of diammonium phosphate (18% N, 20% P) was applied at Patancheru, and 20 kg/ha of single superphosphate (9% P) at Hisar. Seven experiments were conducted; the details are given in Table 1.

In all three seasons crops were protected from pod

Table 2. *Meteorological data for three planting seasons at Patancheru (P) in peninsular India and one at Hisar (H) in northern India*

Year	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
				Total monthly rainfall (mm)								
1982–3 P	193	155	69	180	59	12	0	0	0	13	0	47
1982–3 H	48	106	101	0	0	0	9	23	2	3	108	32
1983–4 P	87	211	305	287	132	1	17	5	1	21	31	0
1984–5 P	92	172	148	99	80	6	0	2	0	20	31	14
				Mean maximum temperatures (°C)								
1982–3 P	34	31	30	30	30	29	28	29	32	37	39	39
1982–3 H	40	38	35	37	34	28	23	20	21	28	31	37
1983–4 P	36	32	29	29	29	28	26	28	30	35	37	41
1984–5 P	35	30	30	30	30	28	29	29	33	37	38	40
				Mean minimum temperatures (°C)								
1982–3 P	24	24	23	23	22	20	17	13	17	20	23	25
1982–3 H	27	27	26	22	18	12	6	5	6	13	16	22
1983–4 P	25	23	23	22	20	14	14	16	18	19	23	26
1984–5 P	24	22	22	22	20	14	14	17	17	20	23	25

Table 3. *Number of days to flowering and maturity of three short-duration pigeonpea genotypes*, 1982–3

	ICPL 4	ICPL 81	ICPL 87
	Patancheru, June sowing		
50% flowering	56	59	64
Maturity			
First flush	96	97	107
Second flush	158	198	158
Third flush	217	258	217
	Patancheru, August sowing		
50% flowering	57	58	60
Maturity			
First flush	87	93	109
Second flush	168	169	170
	Hisar, June sowing		
50% flowering	82	89	91
Maturity	125	130	140

borer (*Heliothis armigera*) infestation by spraying endosulfan (35 EC) at 2 l/ha. The infestation of blister beetle (*Mylabris pustiulata*) was checked by removing the insects by hand.

Data for daily maximum and minimum temperatures (monthly averages) and total rainfall for the three growing seasons are given in Table 2.

Growth analysis

Plant samples for growth analysis were taken from an area of 3·2 m^2 63 days after sowing in 1982–3, and at maturity in all locations and at all sowings. Also, a regular growth analysis was carried out at 20- to 40-day intervals to compare growth and yield of ICPL 87 with BDN 1 in the 1984–5 season. The area sampled each time ranged from 1·4 to 3·24 m^2. In each sample, all the plants from the area sampled were counted and their fresh weights recorded. Then five randomly selected plants from this sample were used for further observations. Their fresh weights were taken and leaf areas measured on an automatic leaf area meter. Separated plant parts were oven-dried at 80 °C for about 48 h and weighed. The total dry matter per unit area and per plant were then calculated.

Yield harvests

The seed yield estimates were from areas of 12–18 m^2. The crop was harvested when about 90% of its pods had matured. Up to three harvests were possible from the three short-duration genotypes in trials at ICRISAT Center. In order to maximize ratoon harvests, the first and second harvests were usually done by picking the mature pods by hand. However, the first harvest of ICPL 4 and ICPL 81 sown in June 1982 was done by cutting off the stems at about 60 cm from ground level. The harvested pods, or stem material with pods, were dried either in the sun or in a 40 °C oven, and threshed. The moisture content of the grains weighed for yield

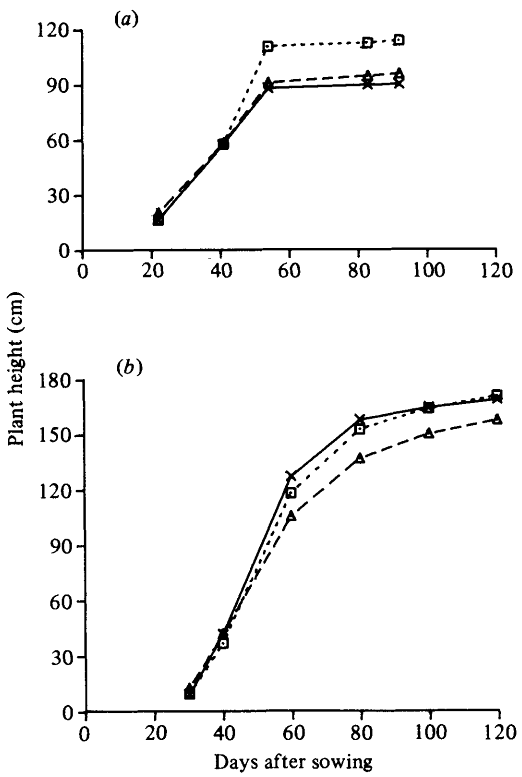

Fig. 1. Mean plant height of three short-duration genotypes, ICPL 4 (×——×), ICPL 81 (□-----□) and ICPL 87 (△----△) in June sowing at (a) Patancheru and (b) Hisar, 1982–3.

estimation was about 9–10%. Harvest index was calculated as the ratio of seed yield to total above-ground dry matter, excluding fallen leaves.

RESULTS

Location effects

Phenology and crop growth

In the 1982–3 season at Patancheru, the June and August sowings of all three short-duration genotypes, ICPL 4, ICPL 81 and ICPL 87, flowered and matured about a month earlier than at Hisar (Table 3).

By maturity all three genotypes had grown taller at Hisar than at Patancheru (Fig. 1). The final height attained by the crop at Hisar was 160–170 cm and at Patancheru, 90–110 cm in the June sowing; and 60–70 cm in the August sowing at Patancheru (not shown in the Figure).

Plants grown at Hisar accumulated more dry matter than the plants from either sowing at Patancheru (Table 4). At Patancheru the June sowing produced more dry matter than the August sowing both at 63 days after sowing (DAS) and at maturity. The dry-matter production at 63 DAS and at maturity was greater for ICPL 87 than for the other genotypes. The August-sown plants at Patancheru accumulated less leaf area than those sown in June (Table 5). The leaf area index attained by ICPL 87 at 63 DAS was more than that for the other two genotypes. It also retained a greater leaf area index at first-flush maturity.

Seed yield at the first harvest

The mean first harvest yield in the June sowing at Patancheru was similar to that at Hisar, about 2·3 t/ha (Table 6). Yields were lowest for the August sowing at Patancheru. There were significant genotypic differences in yield. ICPL 87 gave the highest yield at Hisar and in the August sowing at Patancheru, whereas in the June sowing at Patancheru ICPL 81 gave the highest yield. ICPL 4 gave the lowest yield in all trials.

Mean harvest indices for the June and August sowings at Patancheru for the first harvest were higher than at Hisar (Table 7). Significant genotypic differences in harvest index occurred only for the crop sown in June at Patancheru.

Seed yield in subsequent harvests

At Patancheru, the crops sown in June produced two additional flushes of flowers, and the August sowing only one. The number of days to maturity of the second and third flushes are also given in Table 3. The second harvest yields at Patancheru were as high as 2 t/ha for the June sowing and 0·96 t/ha for the August sowing in ICPL 87. These were significantly higher than for the other two genotypes (Table 6). In the June sowing at Patancheru, the second harvest yield of ICPL 87 may not be directly comparable with the other genotypes since this was harvested by ratooning rather than hand-picking. However, considerable regrowth had occurred for ICPL 81 before it produced a second harvest, which is indicated by the longer time taken by this genotype to reach second-flush maturity (Table 3). In a comparison of the effects of ratooning and hand-picking, this genotype gave about 17% lower second harvest yield with ratooning (unpublished results). The June sowing at Patancheru produced a third flush where yield of ICPL 87, at about 1 t/ha, was significantly higher than that for the other two genotypes. The total yield from three harvests was as high as 5·2 t/ha for ICPL 87, significantly higher than for the other two genotypes. In the August sowing, the total yield of two harvests of ICPL 87 was also significantly higher than for the other two genotypes.

Table 4. *Total dry matter (t/ha) of three short-duration pigeonpea genotypes* 1982–3

	At 63 DAS			At maturity		
	Patancheru		Hisar	Patancheru		Hisar
Genotype	June sowing	August sowing	June sowing	June sowing	August sowing	June sowing
ICPL 4	3·70	1·54	4·17	6·30	2·12	7·33
ICPL 81	3·54	1·67	4·63	6·50	2·77	9·29
ICPL 87	3·89	1·95	5·06	8·27	3·68	11·86
S.E.	0·153	0·104	0·335	0·200	0·205	0·064
Mean	3·71	1·72	4·62	7·02	2·86	9·49

DAS, days after sowing.

Table 5. *Leaf area index of three short-duration pigeonpea genotypes, grown at Patancheru,* 1982–3

	At 63 DAS		At maturity	
Genotype	June sowing	August sowing	June sowing	August sowing
ICPL 4	3·05	1·51	1·29	0·33
ICPL 81	2·85	2·02	0·75	0·59
ICPL 87	3·49	2·92	2·25	1·70
S.E.	0·204	0·147	0·143	0·095
Mean	3·13	2·15	1·43	0·87

DAS, days after sowing.

Table 6. *Mean seed yields (t/ha) of three short-duration pigeonpea genotypes,* 1982–3

	ICPL 4	ICPL 81	ICPL 87	S.E.	Mean
		Patancheru, June sowing			
First harvest	2·15	2·51	2·21	0·053	2·29
Second harvest	0·67	1·13	2·04	0·050	1·28
Third harvest	0·23	0·24	0·97	0·025	0·48
Total	3·06	3·87	5·22	0·084	4·05
		Patancheru, August sowing			
First harvest	0·94	1·05	1·31	0·055	1·10
Second harvest	0·35	0·53	0·96	0·024	0·60
Total	1·28	1·58	2·27	0·075	1·71
		Hisar, June sowing			
Total (single harvest only)	1·97	2·35	2·58	0·197	2·30

Sowing date effects

In the date-of-sowing experiment conducted on the vertisol in 1983–4, ICPL 81 and ICPL 87 gave maximum first-harvest yields in the June sowing, with yield declining more or less linearly with later sowings (Table 8). The first-harvest yields of ICPL 87 in the June and August sowings of 1983–4 were similar to those obtained on the alfisol in the 1982–3 season (Table 6). However, the yield of ICPL 81 was lower in the June sowing of the 1983–4 season. The total dry matter recorded at first-flush maturity also declined with a delay in sowing date but more steeply than the first harvest yield (Table 8).

The second-harvest yields in this experiment were very low owing to a heavy pod fly (*Melanagromyza obtusa*) attack. The second-harvest yield declined further at later sowings (Table 8). The total yield of two harvests was significantly greater for the June sowing and for ICPL 87.

Significant sowing date and soil type interactions for the first harvest, second harvest and total yields were observed in genotype ICPL 87 in the 1984–5 season (Fig. 2). The first-harvest yields on alfisol were greatest in the 11 June sowing, with yields declining more or less linearly with later sowings, which were done at 15-day intervals. On the vertisol, a significant decline in yield occurred only between

Table 7. *Harvest index of three short-duration pigeonpea genotypes*, 1982–3

	Patancheru		Hisar
	June sowing	August sowing	June sowing
ICPL 4	0·38	0·43	0·28
ICPL 81	0·43	0·41	0·26
ICPL 87	0·30	0·40	0·22
s.e.	0·010	0·020	0·014
Mean	0·37	0·42	0·25

Table 8. *Effect of date of sowing on seed yields (t/ha), total dry matter (t/ha) and harvest index at first harvest of two short-duration pigeonpea genotypes grown on a vertisol at Patancheru*, 1983–4

	June		July		August		
	ICPL 81	ICPL 87	ICPL 81	ICPL 87	ICPL 81	ICPL 87	s.e.
First harvest yield	1·62	2·21	1·35	1·56	0·98	1·00	0·061
Second harvest yield	0·57	0·39	0·20	0·33	0·03	0·08	0·032
Total yield	2·19	2·60	1·55	1·90	1·00	1·09	0·085
Total dry matter (at first harvest)	5·68	5·83	3·46	3·95	2·35	1·80	0·213
Harvest index (at first harvest)	0·31	0·42	0·42	0·40	0·42	0·48	0·016

s.e. for comparing the genotypes at same level of sowing date are: first harvest: 0·050; second harvest: 0·026; total yield: 0·066; total dry matter: 0·205; and harvest index: 0·017.

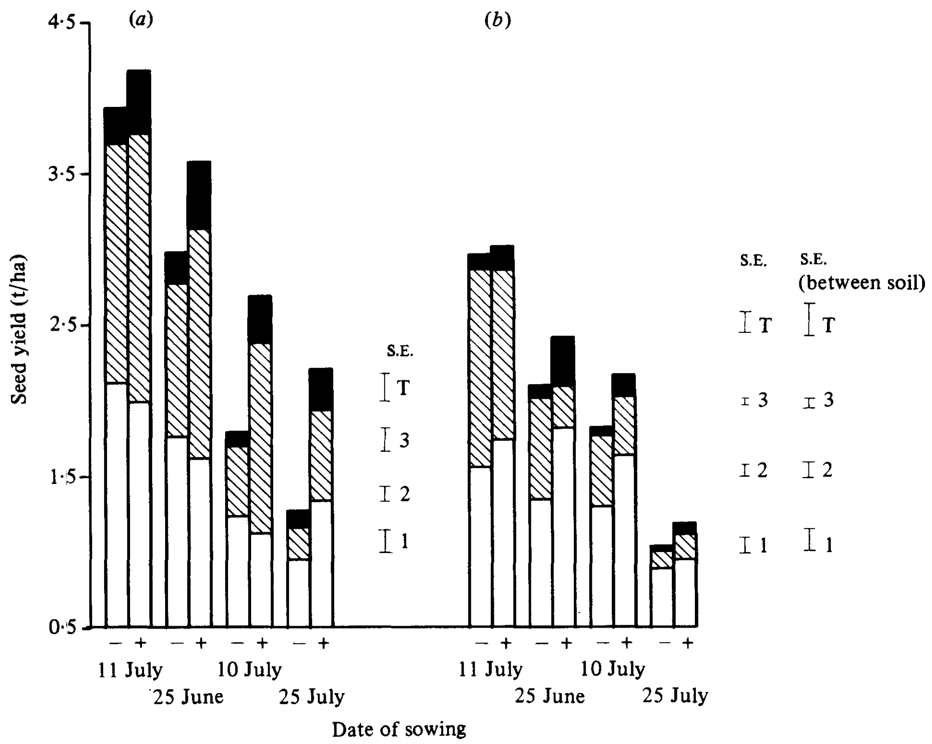

Fig. 2. Yield response of ICPL 87 grown without (−) and with (+) irrigation to four sowing dates on (*a*) an alfisol and (*b*) a vertisol, 1984–5. □, 1, First flush yield; ▧, 2, second flush yield; ■, 3, third flush yield; total bar, T, total yield.

Table 9. *Effect of date of sowing on the yield components of a short-duration pigeonpea genotype ICPL 87 (pooled data of an alfisol and a vertisol) at Patancheru, 1984–5*

	Date of sowing				
Yield component	11 June	25 June	10 July	25 July	S.E.
No. of pods/m²					
First harvest	579	551	461	432	27·2
Second harvest	556	324	277	151	23·7
Third harvest	151	187	118	99	19·9
No. of seeds/pod					
First harvest	3·37	3·34	3·58	2·87	0·242
Second harvest	2·75	2·82	2·69	2·21	0·092
Third harvest	2·20	2·28	2·36	2·11	0·164
100-seed weight (g)					
First harvest	9·88	8·96	8·84	8·63	0·352
Second harvest	9·49	9·40	8·60	7·97	0·243
Third harvest	7·32	6·57	5·91	5·81	0·397

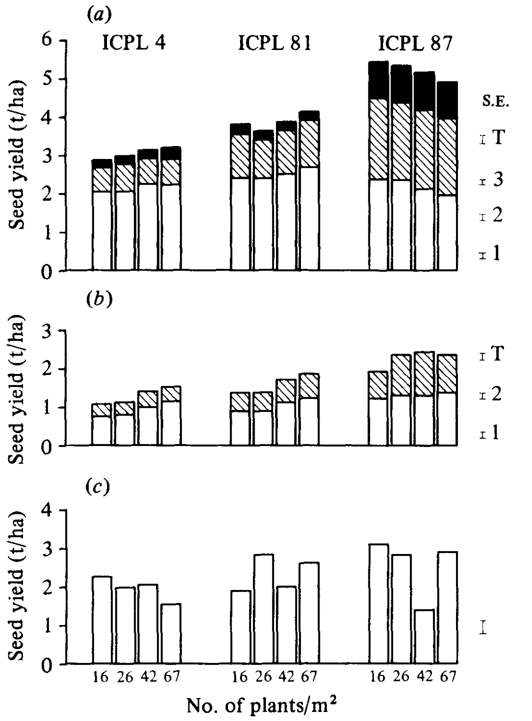

Fig. 3. Yield response of three short-duration genotypes ICPL 4, ICPL 81 and ICPL 87, at four plant population densities in June (*a*) and August (*b*) sowing at Patancheru and June sowing at Hisar (*c*), 1982–3. □, 1, First flush yield; ▧, 2, second flush yield; ■, 3, third flush yield; total bar, T, total yield.

10 and 25 July. The second-harvest yield on the alfisol, which was significantly greater than on the vertisol, declined less steeply with delayed sowing. This decline in yield in delayed sowings occurred even with irrigation. In fact there was a significant negative response to irrigation in the second-harvest yield on the vertisol. On the alfisol, the response to irrigation was positive in the second harvest. For the third harvest the response to irrigation was positive on both soils. Overall, there was a significant positive response to irrigation in total yield on the alfisol but no response on the vertisol.

We also studied the relationship of total dry matter at first-flush maturity (in different experiments and different sowings) with the number of days to maturity, mean daily temperature prevailing during the crop growth period and growing degree days (obtained by multiplying growth duration by the differences between mean daily temperature and base temperature). The relationship was highly significant only for daily mean temperatures ($r = 0{\cdot}91$, $n = 11$) and growing degree days ($r = 0{\cdot}75$, $n = 11$).

The yield component that declined most because of delayed sowing was the number of pods/m², followed by the 100-seed weight and number of seeds per pod (Table 9). A similar pattern of decline in these three components was observed from the first to the third harvest.

Spacing effects

In the June sowing at Patancheru in 1982–3, the main effect of spacing was not significant but the genotype × spacing interaction was (Fig. 3). ICPL 4 and ICPL 81 gave higher first-harvest yields at higher densities (42–67 plants/m²) and ICPL 87 gave higher yields at lower densities (16–26 plants/m²). The second-harvest yield was less affected by plant population density. At the third harvest, yields were similar at all spacings, except for ICPL 4. About 45% of the plants of this genotype had died by third-flush maturity, compared with 32% in ICPL 81 and 6% in ICPL 87. The total yield responded in a manner similar to the first-

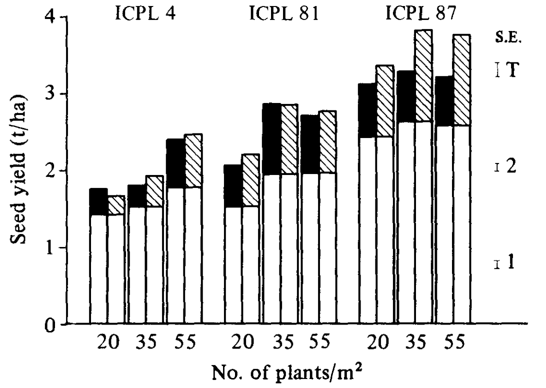

Fig. 4. Yield response of three short-duration genotypes, ICPL 4, ICPL 81 and ICPL 87, at three plant population densities on an alfisol, Patancheru, 1983–4. □, 1, First flush yield with no irrigation; ▨, 2, second flush yield with irrigation; ■, 2, second flush yield with no irrigation; total bar, T, total yield.

harvest yield. In the August sowing, the first-harvest, second-harvest and total yields were greatest at the densest plantings for all genotypes. At Hisar, there was no clear effect of plant population density on yield.

On the vertisol in 1983–4, the response of ICPL 81 and ICPL 87 to spacing was similar to that on alfisol and interaction between sowing date and plant population density was not significant. Therefore, the results of response to spacing on only the alfisol are presented (Fig. 4). The mean first-harvest yield was 1·58 t/ha for ICPL 4, 1·82 t/ha for ICPL 81 and 2·56 t/ha for ICPL 87, the differences being significant. The first-harvest yield of ICPL 4 increased as density increased from 20 to 55 plants/m^2, but yields of ICPL 81 and ICPL 87 increased only up to 35 plants/m^2. The yield at 55 plants/m^2 did not differ significantly from yield at 35 plants/m^2 in the latter two genotypes. The pattern for the second-harvest and total yield was similar to that observed for the first harvest.

Irrigation applied during the second flush increased the yield of ICPL 87 only. The second-harvest yields in general were lower compared with other seasons. There was over 40% pod fly damage, and this could be the reason for the lower yields. ICPL 87 yielded 1·1 t/ha with irrigation and 0·73 t/ha without irrigation. The second-harvest yields of ICPL 81 were similar to those of ICPL 87 when not irrigated, whereas with irrigation ICPL 87 gave significantly higher yields. The yield of ICPL 4

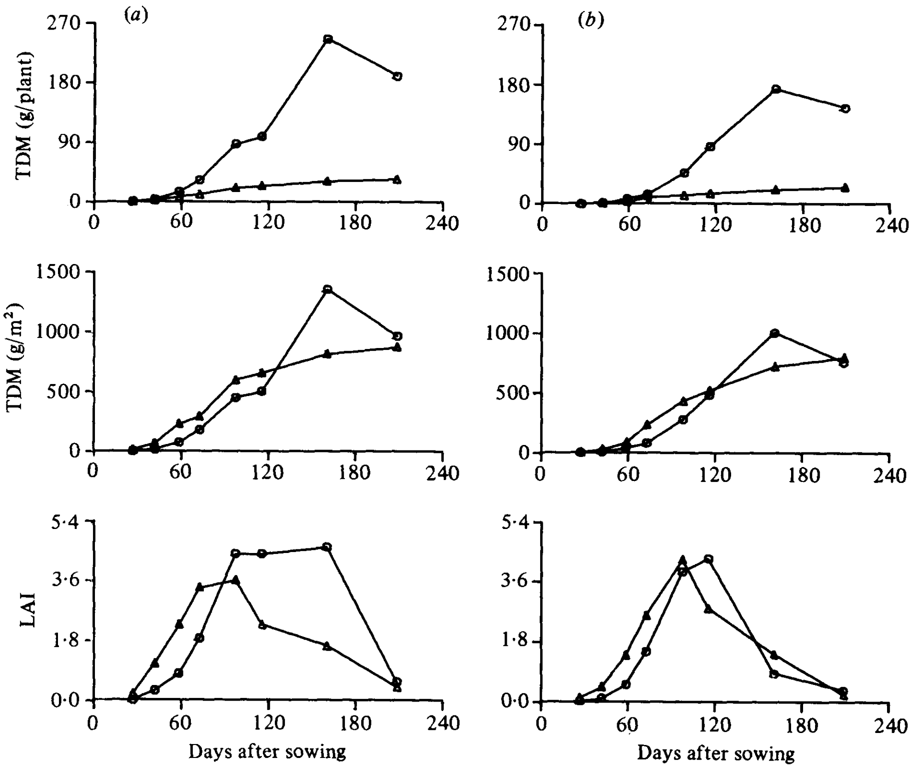

Fig. 5. Total dry matter (TDM) and leaf area index (LAI) accumulation in a short-duration genotype ICPL 87 (△) and a medium-duration genotype BDN 1 (○) on (a) an alfisol and (b) a vertisol, Patancheru, 1984–5.

Table 10. *Comparison of phenology, seed yield and total dry matter of a short-duration (ICPL 87) with a medium-duration (BDN 1) pigeonpea genotype grown at Patancheru, 1984–5*

	BDN 1		ICPL 87		
	Alfisol	Vertisol	Alfisol	Vertisol	S.E.
Days to 50% flowering	113	127	79	78	NA
Days to first-flush maturity	183	182	123	122	NA
Days to second-flush maturity	—		197	196	NA
First-harvest yield (t/ha)	2·34	2·40	2·38	1·79	NA
Second-harvest yield (t/ha)	—	—	1·71	1·36	NA
Total yield (t/ha)	2·34	2·40	4·09	3·15	0·106
Yield (kg/ha per day) first harvest	12·8	13·2	19·4	14·7	NA
Yield (kg/ha per day) first and second harvest	—	—	20·8	16·1	NA
Total dry matter (t/ha)	9·69	7·64	8·70	8·02	0·341
Harvest index (for total yield)	0·24	0·31	0·47	0·39	0·011

S.E. for comparing the genotypes at the same levels of soil are: total yield, 0·102; total dry matter, 0·427; harvest index, 0·014. NA, Not analysed.

was the lowest of all the genotypes, with and without irrigation. The total of two flush yields was greatest for ICPL 87, 3·7 t/ha with irrigation given during the second flush, and 3·4 t/ha without irrigation.

Comparative productivity of ICPL 87 and BDN 1

ICPL 87 attained greater growth rates than BDN 1 in the initial stages even though the growth of individual plants was initially similar (Fig. 5). The higher dry-matter accumulation/m^2 of ICPL 87 in the initial stages was probably due to the higher plant population density at which it was grown, compared with BDN 1. Development of the leaf area index was also faster in ICPL 87 for this reason (Fig. 5). On both soils, ICPL 87 attained a maximum leaf area index of 3–4 by 125 DAS.

The total yield from two harvests of ICPL 87 was 4·09 t/ha on the alfisol and 3·15 t/ha on the vertisol. This was significantly higher than BDN 1, which gave 2·34 t/ha on the alfisol and 2·40 t/ha on the vertisol in one harvest (Table 10). Productivity per day was also higher in ICPL 87. The total dry-matter yield of ICPL 87 was about 90% of BDN 1 on the alfisol, while on the vertisol it was slightly higher than that of BDN 1. The harvest index, calculated on the basis of yields obtained in similar periods, ranged from 39 to 47% for ICPL 87 and from 24 to 31% for BDN 1 in two soils.

DISCUSSION

The Hisar location in northern India, being at a higher latitude than Patancheru, has longer photoperiods, from the longest day in June (when pigeonpea is usually sown) to the September equinox. Further, mean daily temperatures during the above growing period are 4–5 °C higher at Hisar than at Patancheru. Since both shorter photoperiods and moderate temperatures (25–30 °C) induce early flowering in pigeonpea (McPherson, Warrington & Turnbull, 1985), it was not surprising that all three genotypes flowered and matured about 1 month earlier at Patancheru than at Hisar. This shorter crop growth duration at Patancheru could have contributed to the lower growth and dry-matter production of all three genotypes there. Further, owing to the responsiveness of pigeonpea growth to high temperatures (McPherson *et al.* 1985; Sheldrake, 1984), a 4–5 °C lower temperature during the rainy season at Patancheru might have also contributed to the decreased dry-matter production at this location. Perhaps the decline in dry-matter production with delayed sowing at Patancheru may also be one of the major factors responsible for yield decline with delayed sowing, particularly since phenological differences between different sowings were not very large.

Although there were growth differences at Hisar and Patancheru, the yields were similar, at about 2·3 t/ha for the June sowing, mainly because of the higher harvest index at Patancheru. The environmental conditions that control the partitioning of the dry matter in pigeonpea are not precisely known. In soya bean, continuous short-day photoperiods after flowering have been reported to increase the dry-matter accumulation in pods at the expense of vegetative tissues (Thomas & Raper, 1976). At Patancheru, a further improvement in harvest index of all genotypes was observed when sowings were delayed, but it was not sufficient to offset the decline in total dry matter and, therefore, yield declined. Thus, it may not be desirable to sow these genotypes late, to avoid the rains, which are suspected of interfering with the pod formation (Sharma, Saxena & Green, 1978) during the reproductive phase. Further, the seed size may also decline with delayed sowing.

Spence & Williams (1972) have emphasized that a reduction in plant size of pigeonpea due to inductive thermo-photoperiods can be compensated for by increasing plant density. In the present experiment, the responsiveness of pigeonpea to dense sowing appeared to increase in the order: at Hisar, in the June sowing at Patancheru, and in the August sowing at Patancheru. However, delayed sowing caused such a severe reduction in total dry matter that even a very high density of 66 plants/m^2 could not fully offset the decline in the single plant yield. ICPL 87 responded to spacing somewhat differently from the other two genotypes in the June sowing at Patancheru. A density of 25–35 plants/m^2 appeared optimal for this genotype. The lower optimum plant density of this genotype may be due to its slightly longer duration and greater dry-matter production. The optimum density for this genotype was 5–7 times higher than considered optimum for medium-duration genotypes grown in peninsular India (Rao, Venkataratnam & Sheldrake, 1981). In three seasons, ICPL 87 gave over 2 t/ha in the first harvest, which is much higher than the yields reported earlier (about 0·6 t/ha) of other short-duration pigeonpea genotypes, which were grown at a density of 8 plants/m^2 in peninsular India (Sharma *et al.* 1978).

Pigeonpea is intrinsically a perennial plant. After the first harvest the warm winter weather at Patancheru permitted up to two additional harvestings from all the three short-duration genotypes, ICPL 4, ICPL 81 and ICPL 87. At Hisar, the subsequent weather during winter becomes too cool for the growth and survival of pigeonpea so multiple harvests were not attempted. At Patancheru, even among the limited genotypes tested there were significant genotypic differences in the second- and third-harvest yields, suggesting the possibility of selecting genotypes particularly suited to multiple harvesting. ICPL 87 had better second- and third-harvest yield potential than ICPL 4 and ICPL 81 which may be related to its higher leaf area retention at first-flush maturity. It may also be that this genotype is more perennial than the other genotypes tested. Owing to a good multiple-harvest potential, ICPL 87 gave as much as 5·2 t/ha in the 1982–3 season, 3·6 t/ha in the 1983–4 season and 4·1 t/ha in the 1984–5 season. These yields are far higher than those of medium-duration pigeonpea cultivars grown in the Patancheru environment. In a comparison of productivity, ICPL 87 outyielded BDN 1, a medium-duration genotype of pigeonpea, by producing two harvests compared with the one of the latter over a similar period. Further, the shorter duration of ICPL 87 allowed more plants to be used per unit area, resulting in higher initial crop growth rates and quicker canopy development than for BDN 1, both of which are considered important for the monoculture of pigeonpea (Willey *et al.* 1981).

The multiple-harvest potential, particularly of ICPL 87, appeared better on the alfisol than on the vertisol, both with and without irrigation. This was rather unexpected, at least without irrigation and at the delayed sowings, since vertisols have a much higher water-holding capacity than alfisols. With irrigation, the second-harvest yield significantly increased on the alfisol whereas on the vertisol, no such yield increases were observed. Difference in the second-harvest yield therefore became even more pronounced between the two soils. A similar observation has been made by Venkataratnam & Sheldrake (1985) for the second-harvest yield of medium-duration genotypes. The exact reasons for this are not known. Whether biological nitrogen fixation, which is generally poorer on vertisols than on alfisols (Kumar Rao *et al.* 1981), is a limiting factor for the second- and the third-harvest yield on vertisols is being presently examined.

The potential for multiple harvests of pigeonpea has recently been confirmed in the lowland tropical region (Tayo, 1985), using a different genotype. Although the results reported here on the potential of short-duration pigeonpea for multiple harvests are from one location, the practical feasibility of multiple harvests has been confirmed in large demonstrations conducted in farmers' fields at other locations in peninsular and central India using ICPL 87. It is therefore expected that such a system should be feasible in areas where winters are mild (e.g. minimum temperatures above 10 °C).

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