PULSE PHYSIOLOGY
Progress Report 1982-83

Part I
Pigeonpea Physiology

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PIGEONPEA PHYSIOLOGY

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SUMMARY

I. Introduction

This year's rainfall (741.6 mm) at ICRISAT Center was close to the long term average (800 mm) and its distribution formed a somewhat bimodal pattern.

II. Intensive cropping of extra-early pigeonpeas

Three extra-early cultivars, ICPL 4, ICPL 87 (both determinate) and ICPL 81 (indeterminate) were planted at four densities 16, 26, 42 and 67 plants/sq-m at 2 dates on a Alfisol (June and August) at ICRISAT Center and in June on a Entisol at Hisar. The yields of the first harvest made in September at ICRISAT Center at optimum spacing were 2250, 2380 and 2690 kg/ha in cv. ICPL 4, ICPL 87 and ICPL 81 respectively. Genotype x spacing interactions were significant. These cultivars gave second and third harvests also where ICPL 87 gave the highest yield, 2120 and 1000 kg/ha in the second and third harvest respectively. The total yield of this cultivar for the June sowing at 16 plants/sq-m was 5450 kg/ha in 217 days. Two harvests were made of the three cultivars in the August sowing. Response to plant density was positive in the first harvest, but yields were lower than for the first harvest in the June sowing. Cv. ICPL 87 gave significantly more yield than the other two cultivars, in both first and second harvests.

At Hisar only one harvest was made. Although total dry matter produced was higher than in the June sowing at ICRISAT Center, grain yields were similar. There was no clearcut response of plant density. Cv. ICPL 87 gave higher yield than the other two cultivars at Hisar.

III. Response of medium duration cultivars to irrigation given during their reproductive phase

Three cultivars, C 11, BDN 1 and ICP 1-6 were sown on both Alfisol and Vertisol at the beginning of the rainy season. The effect of three irrigations given in mid-October, mid-November and mid-December was compared with unirrigated controls. Irrigations resulted in 100% increase in yield on Alfisol (from 1000 to 2000 kg/ha) and 19% on Vertisol (from 1800 to 2100 kg/ha) suggesting that moisture stress during the reproductive phase of medium cultivars may be a major limiting factor for yield especially on Alfisol.

IV. Response to spacing of 10 medium duration genotypes grown in the rainy season

The mean yields of ten medium duration cultivars declined significantly on both Vertisol and Alfisol with increasing plant density. The mean yields at 4.4, 13.2 and 44.4 plants/sq-m were 1271, 1064 and 682 kg/ha on Alfisol and 1930, 1800 and 1630 kg/ha on Vertisol respectively. On both soils the yields of the erect cvs HY 4 and HY 8 were not significantly affected by planting density whereas spreading and semi-spreading cultivars generally gave lower yields as the planting density was increased.

V. Effect of plant density and irrigation on post-rainy season Pigeonpea

The interaction between plant populations (25, 42, 67, 100/sq-m) and irrigation was studied in two medium maturity cultivars, C 11 and AS 71-37. Three irrigations given during the vegetative, late vegetative and reproductive phases of the crop increased the mean yield by 90% (from 800 to 1520 kg/ha) and the total dry matter by 70% (from 1920 to 3260 kg/ha). The lowest plant population gave significantly less yield and total dry matter than other populations and was therefore suboptimal. The yields were not significantly different at the higher spacings although 67 plants/sq-m gave the highest yield. There was no significant interaction between irrigation and plant population for yield and total dry matter.

VI. Effect of temperature on flowering and pod set in pigeonpea

One of the reason for the low yields of medium duration cultivars may be that their reproductive phase takes place during the winter when the cool nights (with temperatures as low as 8 to 10°C), may reduce or prevent pod set. In a preliminary experiment using ICPL 87, no pod set was observed with night temperatures of 7 °C during the reproductive phase whereas at 15 °C the pod set was normal. This suggested that the critical night temperature for pod set in this cultivar lies between 7 and 15 °C.

VII. Some preliminary observations on the effect of low temperatures on pod set under north Indian conditions.

Late maturing pigeonpea grown in north India generally start flowering in late November or December, before the coldest part of the year and although flowering continues throughout the winter, little pod set take place until the weather becomes warmer in February or March. The low temperature seem to be directly or indirectly responsible for the failure of pod set. There appears however, to be genotypic differences in tolerance to low temperature.

VIII. Compensatory ability of pigeonpea

Pigeonpea cultivars were observed to differ in their ability to compensate for mechanical damage to developing pods. HY 3A was inferior to ICP 1 while APAU 2208 has shown an exceptional ability to recover after heavy pest attack and was able to compensate completely for pod loss or damage.

IX. Effect of clipping of apical bud on growth and yield

Clipping of apical bud at 3 weeks after sowing of cv. C 11 in rainy season (at 75 x 20 cm spacing) increased the seed yield by 10% over control which was significant. However, no increase in yield was observed when clipping was done at 6, 9 and 12 weeks after sowing.

X. Screeing for tolerance to salinity

The performance of 27 advanced breeding lines was compared with tolerant and susceptible checks in a naturally saline field. The field had a gradient of salinity and the rows to be screened were planted in the direction of this gradient. Eight lines were found tolerant. The same 27 lines were screened in pots using saline soil collected from the field. Six lines were found tolerant four of which had been tolerant in the field screening.

XI. Screening for waterlogging tolerance

Sixty-seven advanced breeding lines and germplasm lines were screened for waterlogging tolerance in pots along with two checks BDN 1 (tolerant) and HY 3C (susceptible) during April-May. Sixteen lines showed less than 25% mortality under waterlogging conditions.

XII. Effect of soil cracking in yield

The effect of land management systems which result with different cracking patterns was studied with cv C 11 sown in rainy and post rainy season in separate experiments. The rainy season experiment was vitiated by wilt disease and only limited information could be salvaged. The differences in the yield of eastern and western side rows grown on broad beds were apparent, which probably was due to differential pruning of roots on east and west sides of plants. In another experiment conducted in pots kept outside during rainy season, about 33% more roots were recovered from western side of plants than eastern indicating asymmetric root distribution.

In post rainy season crop the overall yield levels were not much affected by land management systems.

XIII. Some preliminary observations on the effect of sterility mosaic disease on flowering

Sterility mosaic disease infection at 10 and 30 days after sowing considerably delayed floral bud initiation and flowering in the susceptible cultivar BDN 1. However, infection at 60, 80 and 100 days did not delay flowering in this cultivar. There was some delay in floral bud initiation and flowering in the ring spot tolerant cultivar ICP 2376. Floral bud initiation in resistant cultivar ICP 7035 was unaffected by infection. In general delay in floral bud development was more than the delay in floral bud initiation.

XIV. Rabi kharif rabi - perennial cropping system

The rabi crops were established in the sprayed and unsprayed Vertisol fields at the end of September. Yield in sprayed in large field plots was 671 kg/ha and in unsprayed 460 kg/ha. Mortality was greater when plants where harvested by cutting at 15 cm above ground level than when cut at 30 cm or when the pods were picked. Mortality in the summer was lower in the unsprayed field after harvest than in the sprayed field. Among the six cultivars possessing resistance or tolerance to sterility mosaic and wilt disease tested in small plots, ICP 1-6 and ICP 8858, which have a common pedigree, were found to perform the best yieldwise.

I. INTRODUCTION

Meteorological and Soil data

In this report we present results from work carried out between June 1982 and May 1983.

The meteorological data for 1982-83 collected at ICRISAT agroclimatological observatory are shown in Fig.1 and Table 1. This years rainfall of 741.6 mm was close to long term (1901-70) average of 800 mm and distribution conformed to a somewhat bimodal pattern during the rainy season. In Table 2 the monthly rainfall is shown together with the deviation from the long term average.

The meteorological data from June 1982 to December 1982, collected at Hisar agroclimatological observatory are shown in Table 3.

Experiments were conducted at ICRISAT Center on Vertisol fields BP-3A, -5, -6B, -11C, BR-4, BUS-6-B, BS-8C on Alfisol field RP-4B, -4C and at ICRISAT cooperative research station at Hisar. The planting dates and fertilizer use are indicated in materials and methods section of each experiment.

Soil samples for analysis of pH, electrical conductivity, available phosphorous were taken at the time of planting. Details of analysis are given in Table 4.

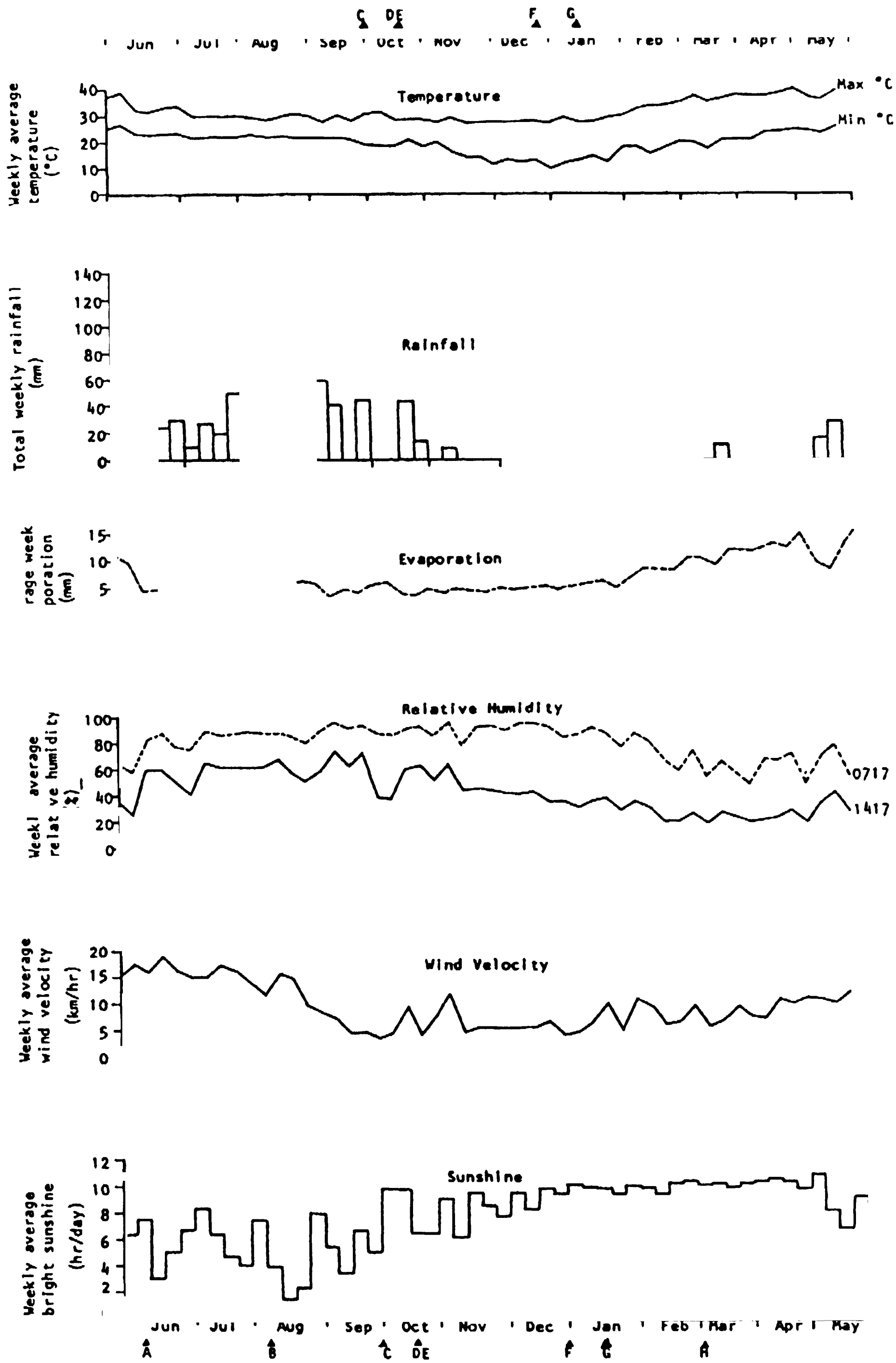
All sowings were done by hand except in field BR-4, and BUS-6B where plantings were done by a tractor mounted machine. Two seeds per hill were planted in hand sowings and plants were thinned two to three weeks after emergence.

Hand weeding was carried out as and when necessary to keep the plots weed free. Plant protection measures were taken as necessary to ensure good control over insect pests by plant protection unit. Irrigation was not given unless otherwise stated in materials and methods sections.

In the previous year sorghum was grown in BP-3A, -5, -6B, and -11C and BUS-6B. Pigeonpea was grown in previous year in BR-4. In Alfisol field RP-4B had chickpea and RP-4C was fallow the previous year. At Hisar chickpea was grown in the field the previous year.

We have referred to our previous Pigeonpea Physiology Reports as PPR 1976-77, 1977-78 etc. We have also referred to chickpea physiology reports in a similar manner.

The report is not a formal publication but a summary of work in progress. It is intended for limited circulation and <u>should not be cited</u>.



A. Sowing rainy season crop
B. Flowering rainy season early cultivars
C. Harvesting rainy season early cultivars
D. Flowering rainy season medium cultivars
E. Sowing post rainy season crop
F. Harvesting rainy season crop
G. Flowering post rainy season crop
H. Harvesting post rainy season crop

Figure 1. Meteorological data for ICRISAT Center (June 1982 to May 1983)

Table 1. Meteorological observations at ICRISAT Center, June 1982 to May 1983

Standard weeks	Dates	Rain-fall (mm)	Temp. max (°c)	Temp. min (°c)	Humidity 0717 (%)	Humidity 1417 (%)	Wind velocity (km/h)	Sunshine (hr/day)	Open pan evaporation (mm/day)
22	28 May to 3 June	23.1	37.3	25.6	63.3	35.3	15.0	6.3	11.0
23	4 to 10 June	0.0	38.8	26.7	58.6	25.3	17.6	7.5	13.8
24	11 to 17 June	131.4	32.6	23.3	83.3	60.0	16.0	3.1	6.6
25	18 - 24 June	24.2	31.8	23.1	87.9	59.7	19.1	5.3	6.7
26	25 June to 1 July	29.1	33.4	23.4	78.0	50.7	15.9	6.7	8.3
27	2 to 8 July	9.2	34.2	23.6	75.9	41.6	15.0	8.2	8.8
28	9 to 15 July	27.3	30.3	22.1	88.9	64.6	14.9	6.4	5.9
29	16 to 22 July	18.9	29.9	22.4	86.9	62.1	17.6	4.7	5.8
30	23 to 29 July	50.0	30.2	22.5	88.1	62.4	16.5	4.0	6.6
31	30 July to 5 Aug	74.4	30.4	22.3	89.1	62.1	14.2	7.5	6.6
32	6 to 12 Aug	24.9	30.0	22.8	87.6	62.3	11.8	3.9	5.4
33	13 to 19 Aug	14.4	28.8	22.4	88.4	67.1	16.1	1.5	5.2
34	20 to 26 Aug	3.4	29.9	22.4	84.6	58.1	15.0	2.4	5.7
35	27 Aug to 2 Sep	0.8	31.5	22.3	79.9	50.6	9.9	8.0	6.3
36	3 to 9 Sep	59.1	30.5	21.8	89.6	58.1	8.4	5.5	5.8
37	10 tc 16 Sep	40.7	28.2	22.0	96.1	73.0	7.4	3.5	3.5
38	17 to 23 Sep	35.4	30.7	22.3	92.4	61.6	4.9	6.7	4.7
39	24 to 30 Sep	44.9	28.6	21.3	94.0	72.4	5.0	5.1	3.9
40	1 to 7 Oct	0	31.5	19.7	86.9	38.3	3.9	9.9	5.5
41	8 to 14 Oct	0	32.2	18.9	86.3	36.6	5.0	9.9	6.0
42	15 to 21 Oct	44.5	28.9	19.0	90.3	59.6	9.6	6.5	4.3
43	22 to 28 Oct	14.3	29.0	21.4	92.9	62.6	4.6	6.5	3.6
44	29 Oct to 4 Nov	2.4	29.2	19.0	86.4	52.0	7.7	9.2	4.7
45	5 to 11 Nov	9.4	28.2	20.8	94.6	63.1	12.0	6.2	4.1
46	12 to 18 Nov	0	29.8	16.7	88.3	44.1	5.0	9.7	4.7
47	19 to 25 Nov	0	27.7	15.0	92.3	44.9	5.8	8.7	4.4
48	26 Nov to 2 Dec	0	27.9	15.0	93.3	42.6	5.7	7.8	4.1
49	3 to 9 Dec	0	27.7	11.9	90.0	40.6	6.1	9.7	4.8
50	10 to 16 Dec	0	28.4	14.1	94.3	40.7	6.5	8.4	4.6
51	17 to 23 Dec	0	28.5	13.1	94.4	42.1	6.6	10.0	4.9
52	24 to 31 Dec	0	28.5	13.7	91.6	35.1	7.1	9.6	5.2

Standard weeks	Dates	Rainfall (mm)	Temp. max (^{o}c)	Temp. min (^{o}c)	Humidity 0717 (%)	Humidity 1417 (%)	Wind velocity (km/h)	Sunshine (hr/day)	Open pan evaporation (mm/day)
1	1 to 7 Jan	0	27.8	10.5	83.6	34.6	4.6	10.3	4.8
2	8 to 14 Jan	0	29.8	12.3	84.9	29.7	5.0	10.1	5.0
3	15 to 21 Jan	0	28.5	13.8	90.6	34.6	6.9	10.1	5.6
4	22 to 28 Jan	0	28.5	15.4	87.3	36.6	10.3	9.6	6.3
5	29 Jan to 4 Feb	0	29.9	13.1	76.0	27.6	5.4	10.2	6.0
6	5 to 11 Feb	0	30.6	18.8	86.6	34.9	11.4	10.1	6.9
7	12 to 18 Feb	0	33.1	18.9	80.1	29.7	9.9	9.6	8.3
8	19 to 25 Feb	0	34.1	16.1	65.6	18.9	6.5	10.4	8.2
9	26 Feb to 3 Mar	0	34.4	17.5	57.3	19.1	6.9	10.5	8.1
10	4 to 10 Mar	0	35.7	20.5	72.7	25.0	10.1	10.3	10.0
11	11 to 17 Mar	0	37.8	20.5	53.6	17.0	6.3	10.4	10.1
12	18 to 24 Mar	12.5	36.0	18.0	63.9	26.4	7.4	10.1	9.1
13	25 to 31 Mar	0	37.3	21.5	56.4	22.7	9.8	10.4	11.8
14	1 to 7 Apr	0	38.4	21.5	46.9	18.4	8.2	10.5	11.7
15	8 to 14 Apr	0	38.3	21.3	54.9	20.0	7.7	10.7	11.9
16	15 to 21 Apr	0	37.8	24.1	54.6	22.6	11.5	10.6	13.0
17	22 to 28 Apr	0	39.2	24.5	71.1	27.7	10.7	9.9	12.3
18	29 Apr to 4 May	0	40.9	25.5	46.7	17.9	11.7	11.1	14.8
19		17.4	38.1	24.7	67.7	33.6	11.4	8.2	9.8
20		28.7	37.0	24.1	77.1	40.4	10.7	6.9	8.0
21		1.2	39.8	26.4	53.0	25.9	12.8	9.3	12.6

Table 2. Summary of rainfall (mm) at ICRISAT Center with departure from the long term average (1901 to 1970) for Hyderabad.

Year	Monthly rainfall												
	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Total
1982-83	207.8	105.4	117.9	180.1	58.8	11.8	0.0	0.0	0.0	12.5	0.0	47.3	741.6
1901-70	115	171	156	181	67	23	6	6	11	13	24	27	800
Difference	+92.8	-65.6	-38.1	-0.9	-8.2	-11.2	-6.0	-6.0	-11.0	-0.5	-24.0	+20.3	-58.4

Table 3. Meteorological observations at Hisar June - December 1982

Standard weeks (1982)	Dates	Temperature °C Max	Temperature °C Min	Humidity (%) 0727	Humidity (%) 1427	Evaporation mm/day	Total rainfall (mm)
22	28 May to 3 June	40.5	22.8	70	28	10.47	0.0
23	4 June to 10 June	41.9	24.9	56	21	10.87	0.0
24	11 June to 17 June	42.3	27.5	52	19	14.01	0.0
25	18 June to 24 June	36.8	24.3	76	44	7.80	43.3
26	25 June to 1 July	38.5	26.9	63	31	11.01	4.5
27	2 July to 8 July	40.3	26.6	59	29	11.32	1.7
28	9 July to 15 July	39.9	27.6	68	32	9.57	5.6
29	16 July to 22 July	37.4	26.5	85	44	8.10	51.6
30	23 July to 29 July	33.0	25.6	90	72	6.16	45.6
31	30 July to 5 Aug	35.0	26.7	90	64	5.05	44.3
32	6 Aug to 12 Aug	34.3	25.3	95	69	4.12	40.1
33	13 Aug to 19 Aug	35.0	26.7	91	63	5.23	0.6
34	20 Aug to 26 Aug	35.1	21.5	94	55	5.03	16.3
35	27 Aug to 2 Sep	36.3	24.2	85	44	6.37	1.0
36	3 Sep to 9 Sep	37.6	23.0	75	34	7.50	0.0
37	10 Sep to 16 Sep	37.6	24.2	84	35	7.27	0.0
38	17 Sep to 23 Sep	38.2	20.6	71	36	7.90	0.0
39	24 Sep to 30 Sep	34.7	18.1	78	29	6.54	0.0
40	1 Oct to 7 Oct	35.4	18.1	74	26	5.2	0.0
41	8 Oct to 14 Oct	35.6	20.4	75	28	5.7	0.0
42	15 Oct to 21 Oct	35.2	19.4	74	27	5.6	0.0
43	22 Oct to 28 Oct	33.3	16.3	76	28	4.9	0.0
44	29 Oct to 4 Nov	29.7	11.9	81	30	4.5	0.0
45	5 Nov to 11 Nov	30.5	14.0	71	32	4.3	0.0
46	12 Nov to 18 Nov	30.1	15.9	80	37	3.5	0.4
47	19 Nov to 25 Nov	26.3	9.9	71	32	3.5	0.0
48	26 Nov to 2 Dec	25.7	7.5	77	32	2.9	0.0
49	3 Dec to 9 Dec	24.5	7.5	77	33	3.5	0.0
50	10 Dec to 16 Dec	23.0	6.0	90	36	2.6	0.0
51	17 Dec to 23 Dec	22.4	4.5	87	27	2.0	0.0
52	24 Dec to 31 Dec	18.9	4.7	92	65	1.6	8.5

Table 4. Soil analysis for the fields used for pigeonpea physiology experiments in 1981-82.

Soil and field No.	Depth of soil (cm)	pH (1:2 soil water extract)	EC 1:2 soil (water extract) (mmhos/cm)	Available P (ppm)	Organic carbon (%)
Black (Vertisol)	0-30	8.10	0.37	3.88	1.24
Field BP-6	30-60	8.15	0.30	<0.5	0.82
(kharif trial)	60-90	8.21	0.32	<0.5	0.71
Black (Vertisol)	0-30	8.1	0.28	1.67	1.58
Field BP-5	30-60	8.15	0.28	<0.50	1.20
(kharif trial)	60-90	8.15	0.27	<0.50	1.38
Black (Vertisol)	0-30	8.40	3.26	1.50	1.28
Field BS-9C	30-60	8.83	2.05	<0.5	1.11
(kharif trial)	60-90	9.15	1.52	<0.5	0.94
Red (Alfisol)*	0-30	7.47	0.36	7.9	-
Field RP-4B	30-60	7.47	0.31	5.1	-
(kharif trial)	60-90	7.38	0.35	10.2	-
Black (Vertisol)	0-30	8.46	0.42	7.00	0.89
Field BP-3	30-60	8.83	0.46	1.50	0.69
(Rabi trial)	60-90	9.04	0.62	1.13	0.71
Black (Vertisol)	0-30	8.28	0.40	1.00	1.02
Field BR-4	30-60	8.28	0.46	0.63	0.74
(Rabi-Kharif-Rabi trial)	60-90	8.40	0.51	<0.50	0.58
Black(Vertisol)	0-30	8.13	0.55	1.63	1.30
Field BUS-6	30-60	8.14	0.49	0.76	1.00
(Rabi-Kharif-Rabi trial)	60-90	8.21	0.53	1.00	0.63
(unsprayed area)					

*samples taken from 1981-82 season.

II. Intensive cropping of extra-early pigeonpeas

In peninsular India, pigeonpeas of medium duration are usually grown. The yields are generally low, both in experimental plots and in farmers' fields, and rarely exceed 2 tons/ha. The reasons for their low yield appear to be related to terminal moisture stress, and also to the cool weather to which the plants are exposed during their reproductive period (PPR 1981-82, Chapter III). By contrast, the reproductive period of early pigeonpeas takes place soon after the monsoon, under more favourable moisture conditions, and before the cool weather sets in. However, yields obtained from such cultivars in earlier years at ICRISAT Center have been around only 1 ton/ha (PPR 1977-78, p.14; PPR 1978-79 p.16). These low yields could have been due to the low plant populations (around 66,000 plants/ha). Such cultivars have given over 3 tons/ha at Hisar, with a poplation of 200,000 plants/ha (PPR 1981-82, pp.40-41) and even higher yields have been obtained in Queensland, Australia. In order to find out if yields at ICRISAT Center could be raised by increasing the planting density, a plant population experiment was conducted, with sowings in both June and August. For comparison, we planted the same trial at Hisar in June.

Materials and Methods

ICRISAT Center

The experiment was conducted on Alfisol field RP-4B, which received 100 kg/ha DAP as basal dose prior to planting. Three cultivars, ICPL-4 (determinate), ICPL-81 (indeterminate), and ICPL-87 (determinate) were planted at 4 spacings (50 x 12, 37.5 x 10, 30 x 8, and 25 x 6 cm) on broadbeds and furrows giving population densities of 16, 26, 42 and 67 plants/square meter respectively. Sowings were done on 15 June and 23 August 1982. The trials for both sowings were laid out as separate experiments in randomised complete block design with two treatment factors. There were 3 replications.

June sowing

Days to 50% flowering during the first flush, and the times to maturity of the three flushes of pods for the June sowing are given in Table 5. The crop received six irrigations on 2-7-82, 23-8-82, 15-10-82, 19-11-82, 14-12-82, and 21-1-83 supplied through the furrows.

Growth analysis was done from 3 square meters area in each replicate at 63 days after sowing. Harvesting of the first and second flush of ICPL-87 was done by pod picking. In case of ICPL-4 and ICPL-81, the first harvest was made by cutting the plants about 65 cm above ground level, and second harvest was done by pod picking. In the case of first harvest, pods picked directly from the plants or from the harvested branches were oven dried at 40 °C before weighing and threshing. At the time of harvest of the third flush, plants were removed from the ground. Plant population at the time of the first harvest in the different treatments is given in Table 6.

August sowing

Days to 50% flowering during first flush, and the times to maturity of the two flushes of pods in August sowing are given in Table 5. The crop received four irrigations on 23-8-82, 15-10-82, 14-11-82, and 21-1-83. Growth analysis was carried out as described above at 66 days after sowing. The first flush of

Table 5. Phenology of extra-early pigeonpea cultivars sown in June and August at ICRISAT Center. (Numbers of days after sowing are indicated in parentheses).

Phenological stage	June sowing (15-6-82)			August sowing (23-8-82)		
	ICPL-4	ICPL-81	ICPL-87	ICPL-4	ICPL-81	ICPL-87
50% flowering	10-8(56)	13-8(59)	18-8(64)	19-10(57)	20-10(58)	22-10(60)
Maturity of 1st flush	13-9(90)	20-9(97)	30-9(107)	19-11(87)	24-11(93)	10-12(109)
Maturity of 2nd flush	20-11(158)	30-12(198)	20-11(158)	7-2(168)	8-2(169)	9-2(170)
Maturity of 3rd flush	18-1(217)	28-2(258)	18-1(217)	-	-	-
Harvest of 1st flush	20-9	24-9	1-10	8-12	7-12	13-12
Harvest of 2nd flush	24-11	17-1	24-11	10-2	10-2	10-2
Harvest of 3rd flush	2-3	2-3	2-3	-		

mature pods was picked by hand, and at the time of second harvest plants were removed from the field. The plant populations in the different treatments were only about 50-60% of theoretical population (Table 6), as a result of mortality due to Sclerotium and Phytophthora sp.

Hisar

Cultivars and spacing treatments were the same as those at ICRISAT Center. The field had received 20 kg/ha P205 as a basal dose prior to sowing. The crop was sown on 18 June 1983. Days to maturity were not recorded in this experiment, but all cultivars had matured within 130-140 days. The crop received three irrigations on 26-6-82, 5-9-82, and 26-9-82.

As in the case of experiments conducted at ICRISAT Center, a growth analysis sample was taken from a 3 square meter area 61 days after sowing.

Owing to bad patches of soil giving much reduced growth in one replication, only data from two replications were analysed. The plant population at the time of harvest was close to the theoretical population at the lower population densities, but was somewhat reduced at the higher densities.

Results and Discussion

Phenology

At ICRISAT Center the time of flowering and to maturity of the three cultivars was very similar in the June and August plantings (Table 5). This indicates that the plants were more or less insensitive from a phenological point of view to the differences in photoperiod and temperature in these periods. Cultivar ICPL-4 was the earliest, maturing in around 90 days; cv. ICPL-81 matured in 93-97 days and cv. ICPL-87 in 107-109 days.

By contrast, at Hisar all three cultivars took between 130-140 days to mature, and also flowered about a month later than at Hyderabad. Cv. ICPL-4 after 82 days, ICPL-81 after 89 and ICPL-87 after 91 days. (The figures for June plantings at Hyderabad were 56, 59, and 64 respectively). At both Hyderabad and Hisar the June plantings were carried out around the longest day; at Hyderabad flowering took place before the September equinox and at Hisar after the equinox. Between the longest day and the equinox, daylengths at Hisar are longer than at Hyderabad, and temperatures higher. The delayed flowering at Hisar indicates that the plants were affected phenologically by the longer photoperiods and/or higher temperatures.

Crop growth

In the June plantings, the plants grew less in the first month at Hisar than at Hyderabad, but then the plant growth rate accelerated, and the plants continued to grow for longer (Fig 2) no doubt partly because flowering took place about a month later than at Hyderabad. At Hisar, all the cultivars grew to a final height of 160-170 cm, whereas in Hyderabad in the June planting the determinate cultivars ICPL-4 and ICPL-87 grew to only about 90 cm; the indeterminate cv. ICPL-81 reached a height of about 110 cm. In the August planting at Hyderabad, there was less growth; the final heights of the determinate cultivars were around 60-70 cm, and ICPL-81, 90 cm.

Table 6. Plant population at the time of first harvest of extra-early pigeonpeas grown at ICRISAT Center and Hisar

Theoretical plant population (plants/m^2)	Cultivar				
	ICPL-4	ICPL-81	ICPL-87	Mean	
ICRISAT Center, June sowing					
67	61.1	58.6	58.0	59.2	
42	39.1	38.9	39.6	39.2	± 0.6
26	24.2	24.1	26.3	24.9	
16	16.2	16.6	16.8	16.6	
		± 1.0			
ICRISAT Center, August sowing					
67	37.5	30.4	34.5	34.2	
42	25.1	23.9	24.3	24.4	± 0.6
26	17.6	14.1	16.0	15.9	
16	11.3	8.8	10.2	10.1	
		+ 1.0			
Hisar , June sowing					
67	39.2	43.0	44.1	42.1	
42	31.0	29.1	33.1	31.1	± 1.1
26	21.9	27.8	22.0	23.9	
16	18.0	15.4	16.1	16.5	
		1.9			

Samples were taken for growth analysis 62-66 days after sowing. In all cases the total dry matter per unit area was highest in the most dense planting, as expected (Table 7). At Hisar more dry matter had been accumulated than in the June-sown plants at Hyderabad; and the latter had accumulated about twice as much dry matter as the August-sown plants (Table 7). These differences are probably largely explicable in terms of temperature, with more growth taking place in the warmer conditions at Hisar than at Hyderabad, and in June sowings than in August sowings (see PPR 1980-81, Chapter II).

The lower dry weights per plant at the higher population densities no doubt reflects the effect of plant-to-plant competition. The data in Table 7 indicates that this was more severe in the June sowing at Hyderabad than in the August sowing or at Hisar. These differences may have been due in part to the different environmental conditions, but in part they reflect the fact that the actual plant populations were lower in the case of the Hisar and August sowings (Table 6).

Leaf Area Indices (LAI) were, not surprisingly, higher in the denser population and higher in the June than the August sowing (Table 8). There were consistent differences among cultivars, with the greatest LAI in cv ICPL-87. Interestingly, in both plantings, the LAI of this cultivar declined much less as the plants matured than in the other cultivars, and at maturity the LAI was still quite high. This difference was clearly apparent in the field; the plants looked greener and less senescent than the other cultivars. This unusual retention of leaves by cv ICPL-87 may be one reason why this cultivar was able to produce such good second harvest yields.

<u>Plant mortality</u>

In the June sowing there was practically no plant mortality at the time of the harvest of the first flush, but thereafter many of the plants of cv ICPL-4 died, and some of ICPL-81. By the time of the harvest of the third flush, 45% of the former had died, and 32% of the latter (Table 9). In cv ICPL-87, by contrast, only 6% had died. These differences were highly significant statistically.

In the August sowing, 11% of the plants of cv ICPL-4 had died by the time of the first harvest, and 22% by the second harvest (Table 9). There was little or no mortality in the other cultivars. In cv ICPL-4, the percentage mortality was greatest at the highest population of 670,000 plants/ha (35%), and declined significantly at the lower populations: 22% at 420,000 plants/ha; 16% at 260,000 plants/ha and 15% at 160,000 plants/ha (SE 1%).

There was no reason to think that the mortality in cv ICPL-4 was due to disease; rather, it appeared to be physiological. It may be that this cultivar is close to being an annual in its behaviour, by contrast with cv ICPL-87 which has a marked perennial character, as shown by its good second and third harvest yields (Table 10), and the limited leaf senescence at the time of the maturity of the first flush of pods (Table 8). The mortality of the plants of cv ICPL-4 may well have been increased by moisture stress. In experiments under way in 1983, we have observed that death of the plants occurs in the center of plots grown on Vertisol, but that plants in the borders often survive, probably because they have access to more soil moisture.

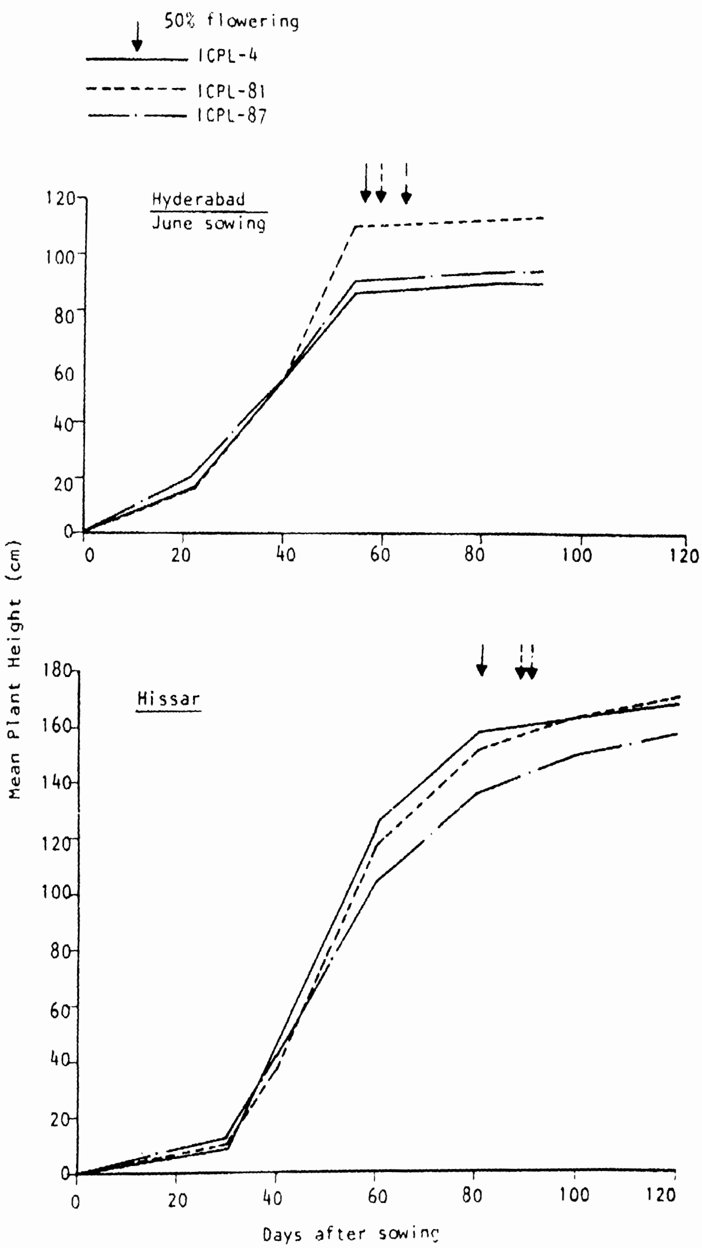


Figure 2. Mean height of extra-early pigeonpea during the growing season after planting in June at ICRISAT Center and Hissar.

able 7. Total dry matter (TDM) per plant and per m^2 in June and August at ICRISAT Center at 63 and 66 days after sowing respectively and in June sowing at Hissar at 62 days after sowing.

Cultivar	Plant pop./ ha	ICRISAT Center				Hissar	
		June sowing		August sowing		June sowing	
		TDM g/pl	TDM g/m^2	TDM g/pl.	TDM g/m^2	TDM g/pl	TDM g/m^2
CPL-4	670,000	8.3	450	5.0	203	9.6	522
	420,000	9.8	397	6.3	171	11.8	499
	260,000	13.6	347	6.6	122	11.7	310
	160,000	17.2	289	9.1	120	15.2	337
ICPL-81	670,000	6.3	408	7.5	255	11.4	573
	420,000	10.5	385	7.8	191	13.4	419
	260,000	13.6	320	9.6	125	12.5	412
	160,000	19.2	301	10.9	97	23.9	448
ICPL-87	670,000	7.2	430	9.8	270	13.7	649
	420,000	11.9	388	10.0	242	8.7	347
	260,000	13.9	369	12.6	163	16.4	514
	160,000	21.3	368	10.3	105	23.2	513
	SE ±	0.97	30.6	1.26	20.7	2.64	67.1

Table 8. Leaf area index of 3 extra-early cultivars in June and August plantings at ICRISAT Center, sampled at 63 and 66 days after sowing respectively, and at maturity.

Cultivar	Population (Plants/ha)	June sowing		August sowing	
		At 63 days	At maturity	At 66 days	At maturity
ICPL-4	670,000	4.1	1.7	2.4	0.3
	420,000	3.4	1.4	1.6	0.4
	260,000	2.9	1.0	1.0	0.3
	160,000	1.6	1.1	0.9	0.3
ICPL-81	670,000	4.1	1.0	3.4	0.8
	420,000	2.8	0.9	2.4	0.4
	260,000	2.3	0.7	1.3	0.7
	160,000	2.1	0.3	1.1	0.4
ICPL-87	670,000	4.6	3.5	4.9	2.7
	420,000	3.8	2.6	3.3	1.4
	260,000	3.3	1.6	2.1	1.5
	160,000	2.4	1 4	1.4	1.1
SE ±		0.41	0.29	0 30	0.19

Overall yield

At Hyderabad, in the June planting, all three cultivars yielded over 2 tons/ha in the first flush. The highest yield was given by cv ICPL-81; but in the August planting and at Hisar cv ICPL-87 yielded best (Table 10).

In spite of the fact that at Hisar the plants grow more and matured about a month later, the yield levels there were similar to those of the first flush at Hyderabad (2 - 2.5 tons/ha). This shows that the extra-early cultivars can do as well, if not better, under peninsular Indian conditions than in the north. This is a very important finding because until now within India extra-early cultivars have been almost exclusively bred for, and tested, under north Indian conditions; and it has been assumed that they would not do well in the peninsular region.

In fact, they are even more promising in peninsular India than in the north, because second and even third harvests can be taken from the same plants. This is not possible in the north owing to the coldness of the winter season. In the June planting at Hyderabad, the second harvest yield of cv ICPL-87 was 2 tons/ha and the third harvest gave 1 ton/ha. The second harvest yields of cvs ICPL-4 and ICPL-81 are not directly comparable, because they were ratooned at the time of the first harvest, which usually gives a lower subsequent yield than simply picking the pods, as was done with cv ICPL-87. But in spite of this disadvantage, the two ratooned cultivars gave second harvest yields which were comparable to the best second harvest yields obtained from medium-duration cultivars at Hyderabad (PPR 1980-81, Chapter VII).

The total yield of cv ICPL-87, 5220 kg/ha, far exceeds any yield previously obtained at ICRISAT Center. Medium duration cultivars rarely yield more than 2 tons/ha in the first harvest (PPR 1981-82, Chapter III) and combined first and second harvest yields have not exceeded 2,900 kg/ha, even with regular irrigation in our yield optimization trials (PPR 1981-82, Tables 17 and 20, this report Tables 20 and 22). Moreover, the second flush of the extra-early cultivars was harvested before the first flush of the medium cultivars had matured. In the case of cv ICPL-87 the productivity of seed per unit time was about twice that of the best yielding medium duration cultivar, BDN-1, grown with high inputs and regular irrigation (Table 11).

Seed quality

Since the first flush of pods in the June sowing developed during the monsoon season, there seemed to be a possibility that the seeds would be affected by mould or by premature germination within the pods. In fact, no such germination was observed, and only in the case of cv ICPL-81 was mould observed on a few seeds, probably those from pods which had partly split open on the plants. The viability of the seeds was tested by germinating 40 seeds of each cultivar on filter paper in petri dishes. Only in cv ICPL-4 was the germination rate low, 68%, but this may have been due more to the relatively high proportion of shrivelled seeds in this cultivar than to disease. In cv ICPL-81, 95% germinated and in cv ICPL-87, 93%.

In experiments being carried out in 1983-84, more attention will be paid to the quality of the seeds in the first and subsequent harvests, in order to check whether pod development during the rainy season has any serious adverse effects.

Table 9. Percentage mortality in 3 extra-early cultivars at the time of harvest of the third flush from the June sowing, and the first and second flushes from the August sowing.

Percentage of plants which were dead

	Cultivar			SE	Significance (F test)
	ICPL-4	ICPL-81	ICPL-87		
June sowing, third flush	45	32	6	2.7	**
August sowing, first flush	11	2	0	0.9	**
August sowing, second flush	22	2	1	0.9	**

Table 10. Yield (kg/ha) of extra-early pigeonpeas in June and August plantings at ICRISAT Center and in June planting at Hissar.

	Cultivar				
	TCPL-4	TCPL-81	TCPL-87	SE±	Significance (F test)
Hyderabad, June planting					
First flush	2153	2505	2208	52.8	**
Second flush	671	1127	2039	49.7	**
Third flush	232	235	971	24.5	**
Total yield	3056	3868	5217	83.8	**
Hyderabad, August planting					
First flush	936	1049	1313	55.4	**
Second flush	348	533	960	23.8	**
Total yield	1284	1582	2273	74.7	**
Hisar , June planting					
Total yield (one flush only)	1973	2352	2576	139.8	

Effects of spacing on yield

In the June sowing at Hyderabad, the cultivars responded differently to spacing (Table 12); ICPL-4 and ICPL-81 gave a better first harvest yield at the higher plant populations (420,000 and 670,000 plants/ha) while ICPL-87 yielded better at the lower populations (160,000 and 260,000 plants/ha). The cultivar x spacing interaction was significant at the 5% level of probability.

In the second harvest there was less effect of population density on yield, although there was still a tendency for cv ICPL-87 to yield best at the lowest planting density (Table 12). In the third harvest, yield was more or less the same at the different densities in cvs ICPL-81 and -87; but in cultivar ICPL-4 it was highest in the most dense planting (Table 12). The total yield from all the harvests largely reflected the pattern seen in the first harvest, with the best yields in cvs ICPL-4 and ICPL-81 at the highest population density, and in cv ICPL-87 at the lowest density (Table 12).

In the August sowing, the first harvest yields were greatest in all cultivars with the most dense population, and least at the lower population densities (Table 13). However, there was less effect of population density in cv ICPL-87 than in the other cultivars.

In the second harvest, yield levels were again generally higher in the more dense plantings, and lowest in the least dense planting (Table 13), and the same pattern was apparent in the data for total yield (Table 13). The mean total yield at 670,000 plants/ha was 30% higher than at 160,000 plants/ha.

The difference between the June and August sowings in response to population density no doubt reflect in part the smaller size of the later sown plants, which would have resulted in less mutual competition; the highest plant population was no longer super-optimal for cv ICPL-87, as it was in the June planting. But in part these results must have been influenced by the fact that in the August plantings the actual plant population were reduced by mortality due to disease in the early stages of growth (Table 6); for example on an average there were only 34 plants/sq.m at highest populations instead of 67.

At Hisar, there was no clear-cut systematic effect of population density on yield, and the data showed some inexplicable fluctuations, most notably in the low yield of cv ICPL-87 at 420,000 plants/ha, which were probably due to the random effects of bad patches of soil. The coefficient of variation in this experiment was relatively high (17.1%).

Last year at Hisar, extra-early cultivars were grown at a spacing of 30 x 10 cm, with a final plant population of around 200,000 plants/ha. This was intermediate between the final population this year at the two lower population densities (Table 1[illegible]). The mean yield of cultivar ICPL-81, at these populations was 2380 kg/ha, and of ICPL-87, 2990 kg/ha. These figures are comparable to last year's yields of 2230 kg/ha and 3420 kg/ha respectively (PPR 1981-82, Table 23).

Table 11. Comparison of productivity of cv. ICPL-87 (extra-early) and cv. BDN-1 (medium duration) planted in June 1982 at ICRISAT Center and grown with high inputs and irrigation on Alfisol.

	ICPL-87 (extra-early)	BDN-1 (medium)
Days to maturity of first flush	107	183
Days to maturity of second flush	158	290
Days to maturity of third flush	217	-
First harvest yield (kg/ha)	2208	2348
Second harvest yield (kg/ha)	2039	409
Third harvest yield (kg/ha)	971	-
Total yield (kg/ha)	5217	2757
Grain productivity (kg/ha/day)		
First harvest	21	13
First + Second harvest	27	10
First + Second + Third harvest	24	--

Table 12. Effect of planting density on the yield (kg/ha) of 3 extra-early cultivars sown in June 1982 at ICRISAT Center.

Population (plants/ha)	Cultivar			
	ICPL-4	ICPL-81	ICPL-87	Mean
FIRST HARVEST				
670,000	2237	2685	1971	2298
420,000	2252	2516	2127	2299
260,000	2064	2423	2356	2281
160,000	2059	2395	2376	2277
Mean	2153	2505	2208	
SECOND HARVEST				
670,000	665	1236	1974	1291
420,000	675	1142	2049	1289
260,000	717	980	2015	1237
160,000	626	1152	2117	1298
Mean	671	1127	2039	
THIRD HARVEST				
670.000	309	220	957	495
420,000	214	218	995	476
260,000	210	237	973	473
160,000	195	267	957	473
Mean	232	235	971	
TOTAL YIELD				
670,000	3210	4140	4902	4084
420,000	3142	3876	5171	4063
260,000	2992	3639	5344	3992
160,000	2880	3815	5449	4048
Mean	3056	3868	5217	

SE (Significance by F test indicated by asterisks	First harvest	Second harvest	Third harvest	Total yield
Spacing	60.9	57.4	28.3	96.8
Cultivar	52.8**	49.7**	24.5**	83.8**
Spacing x Cultivar	105.5*	99.4	49.1	167.6

Table 13. Effect of planting density on the yield (kg/ha) of 3 extra-early cultivars sown in August 1982 at ICRISAT Center.

Population (plants/ha)	Cultivar ICPL-4	ICPL-81	ICPL-87	Mean
FIRST HARVEST				
670,000	1160	1238	1385	1261
420,000	1007	1142	1308	1152
260,000	803	904	1322	1010
160,000	772	914	1236	974
Mean	936	1049	1313	
SECOND HARVEST				
670,000	353	609	977	646
420,000	388	574	1127	696
260,000	332	483	1040	619
160,000	320	465	697	494
Mean	348	533	960	
TOTAL YIELD				
670,000	1513	1847	2361	1907
420,000	1395	1716	2435	1849
260,000	1135	1387	2362	1628
160,000	1092	1379	1933	1468
Mean	1284	1582	2273	

SE(Significance by F test indicated by asterisks	First harvest	Second harvest	Total yield
Spacing	63.9*	27.5**	86.3**
Cultivar	55.4**	23.8**	74.7**
Spacing x Cultivar	110.7	47.6**	149.4

BR

ɔtal dry matter

In both plantings at Hyderabad and also at Hisar, cv ICPL-87 produced considerably more total dry matter at the time of first harvest than cv ICPL-81, which in turn produced more than cv ICPL-4 (Table 15). These differences are probably due at least in part to the differences in growing period, with cv ICPL-87 flowering and maturing latest, and ICPL-4 earliest.

At Hisar, all cultivars grew more than at Hyderabad; the overall mean dry matter was 9490 kg/ha, compared with 7020 kg/ha at Hyderabad in the June planting, and 2850 kg/ha in the August planting. The greater growth at Hisar may be explained partly by the warmer weather (Table 3) and partly by the fact that the growth period was about a month longer. However, in the June and August sowings at Hyderabad, the growth periods were about the same (Table 5), and the much reduced growth in the latter was probably due mainly to the cooler weather during the growing period. Pigeonpea growth rates are known to be reduced as planting is delayed (PPR 1980-81, Chapter II).

At Hyderabad, in both plantings more dry matter was produced at the higher population densities. At Hisar, the data were rather erratic, and no clear effect of planting density was apparent (Table 15).

Harvest index

The highest harvest indices at the time of first harvest were obtained in the August planting at Hyderabad, with an overall mean of 0.42. The mean for the June planting at Hyderabad was 0.37 and at Hisar 0.25.

Only in the June planting at Hyderabad were there significant differences among cultivars, with the highest harvest index (HI) in cultivar ICPL-81 (0.43), the lowest in cv ICPL-87 (0.30), and a HI of 0.38 in cv ICPL-4 (SE 0.01).

In no case were spacing x cultivar interactions significant. The means for spacing effects are given in Table 16. In both plantings at Hyderabad the HI was lowest at the highest population density. Such a decline in HI with increasing plant population has been found previously both in the normal season (PPR 1979-80, Fig.8) and in the post-rainy season (PPR 1980-81, Fig.22).

Yield components

As in previous studies, the component of yield most closely related to yield itself was pod number per unit area.

In all plantings, the 100-seed weight of cv ICPL-87 was higher than in the other cultivars. There was little effect of spacing on 100-seed weight in agreement with previous results from spacing trials in the normal (PPR 1979-80, p.29) and post-rainy seasons (PPR 1980-81, Fig.22).

At Hisar, 100-seed weights were slightly greater than at Hyderabad in the June planting. In the August planting, 100-seed weights were generally lower than in June (Table 17). This is in general agreement with the tendency of post-rainy season pigeonpeas to have lower 100-seed weights than in the normal season (PPR 1976-77, Table 64). In cv ICPL-4 planted in June, the 100-seed weight in the second and third harvests was less than in the first, but no such pattern was apparent in cv ICPL-81, and in cv ICPL-87, there was a decrease only

Table 14. Effect of planting density on the yield (kg/ha) of three extra-early cultivars sown in June 1982 at Hissar.

Population (plants/ha)	Cultivar ICPL-4	ICPL-81	ICPL-87	Mean
670,000	1559	2633	2913	2368
420,000	2065	2014	1418	1832
260,000	1988	2855	2850	2564
160,000	2279	1906	3123	2436
Mean	1973	2352	2576	
SE (Significance by F test indicated by asterisks)				
Spacing	161.5*			
Cultivar	139.8*			
Spacing x Cultivar	279.6*			

Table 15. Effect of planting density on the total dry matter (kg/ha) at the time of first harvest of 3 extra-early cultivars sown in June and August at ICRISAT Center, and at June in Hisar.

Population (plants/ha)	Cultivar			Mean
	ICPL-4	ICPL-81	ICPL-87	
Hyderabad, June Sowing				
670,000	7305	7348	9324	7992
420,000	6520	7241	8335	7365
260,000	5653	5525	7606	6261
160,000	5700	5903	7813	6472
Mean	6294	6504	8269	
Hyderabad, August Sowing				
670,000	2934	3157	4483	3525
420,000	2145	3244	3937	3109
260,000	1817	2319	2819	2318
160,000	1582	2340	3469	2464
Mean	2120	2765	3677	
Hisar, June Sowing				
670,000	5825	10210	15011	10349
420,000	8151	8609	6855	7871
260,000	6835	9992	11958	9595
160,000	8521	8349	13604	10158
Mean	7333	9290	11857	

SE (Significance by F test indicated by asterisks)	Hyderabad, June	Hyderabad, August	Hisar
Spacing	230**	238**	745
Cultivar	199**	206**	645**
Spacing x Cultivar	399	411	1290*

in the third harvest. It is not clear what physiological and environmental factors lead to such variations.

The number of seeds per pod was lowest in cv ICPL-81 in all plantings (Table 18). There was no significant effect of spacing on seed number per pod except at Hisar, where there was a reduction at the higher densities of planting. This tendency has been observed previously at Hyderabad both in the normal (PPR 1979-80, p.29) and post-rainy seasons (PPR 1980-81, Fig.22).

At Hyderabad, in all cultivars, there were fewer seeds per pod in the August than the June planting, fewer in the second harvests than the first, and fewer in the third harvest than the second (Table 18). These reductions may be largely explicable in terms of temperature. From the phenological data in Table 5, and the weather data in Fig.1, it can be seen that the temperature, especially the minimum temperature, was progressively lower during the subsequent reproductive flushes, and lower for the August than the June planting. Lower temperatures could affect seed number per pod by reducing the number of ovules, and/or efficiency of fertilization, and/or by increasing the frequency of seed abortion. We do not know the relative importance of these factors.

Pigeonpea stems are a useful source of firewood, and are of some economic value. At Hisar, the plants were relatively large, and the mean dry weight of stems and branches was around 5.5 tons/ha. At Hyderabad, the plants were smaller, but nevertheless in the June plantings considerable amount of stem material was produced - an average of 3.5 tons/ha at the time of the third harvest of cv ICPL-87. The least productive cultivar, ICPL-4, gave 1.5 tons/ha at this stage. The amount of stem matter was higher at the time of the first harvest - 4.5 tons/ha for cv ICPL-87 and 2.7 tons/ha for cv ICPL-4. The decline by the time of the third harvest may be due in part to the mobilization of stem reserves, and also to the death of some of the plants after the first harvest.

In the August planting, there was little change in stem weight between first and second harvests. Cv ICPL-87 produced 1.7 tons/ha and cv ICPL-4 0.7 tons/ha.

Although at first sight the smaller stature of the extra-early cultivars suggests that they will produce less stem material than the larger medium duration cultivars, in fact, in June planting the amounts were comparable. In 1979-80, for example, even at high plant populations medium duration cultivars grown on Vertisol gave only about 2.4 tons/ha of stem material (PPR 1979-80, Fig.6); and in 1978-79 cv C-11 produced 2.8 tons/ha at normal spacing, and 4.0 tons/ha at the high population density of 278,000 plants/ha (calculated from data in PPR 1978-79, Table 28 on the basis of a seed weight/pod weight factor of 0.67). Therefore the intensive cultivation of extra-early cultivars need not necessarily result in a decline in firewood production, compared with medium duration cultivars, for although the plants are smaller, they are more of them per unit area. However, whether the stems are of comparable utility on firewood to those of medium duration cultivars remains to be seen.

Table 16. Effect of planting density on the mean harvest index of three extra-early cultivars sown in June and August at ICRISAT Center and in June at

Population (plants/ha)	Hyderabad, June	Hyderabad, August	Hisar
670,000	0.33	0.38	0.24
420,000	0.35	0.41	0.23
260,000	0.39	0.45	0.28
160,000	0.39	0.42	0.24
SE ±	0.01	0.02	0.01
Significance by F test	**	NS	NS

Table 17. 100-seed weight (g) of extra-early pigeonpeas in June and August plantings at ICRISAT Center and in June planting at Hisar.

	Cultivar			SE±	Significance (F test)
	ICPL-4	ICPL-81	ICPL-87		
Hyderabad, June Planting					
First flush	6.07	5.52	9.77	0.11	**
Second flush	4.92	7.21	9.91	0.11	**
Third flush	5.54	5.97	8.84	0.17	**
Hyderabad, August Planting					
First flush	4.79	6.07	8.65	0.13	**
Second flush	5.14	5.73	8.43	0.17	**
Hisar June Planting					
First flush	6.14	6.70	10.33	0.42	**

Table 18. Seed number per pod of extra-early pigeonpeas in June and August plantings at ICRISAT Center and in June planting at Hisar.

	Cultivar			SE±	Significance
	ICPL-4	ICPL-81	ICPL-87		F test
Hyderabad, June Planting					
First flush	3.87	3.24	3.68	0.06	**
Second flush	3.47	2.56	3.38	0.06	**
Third flush	1.90	1.73	2.93	0.05	**
Hyderabad, August Planting					
First flush	3.15	3.11	3.28	0.06	NS
Second flush	2.31	2.00	2.77	0.08	**
Hisar , June Planting					
First flush	3.02	2.96	3.21	0.14	NS

Conclusions

These results demonstrate the extraordinarily high yield potential of extra-early cultivars under peninsular Indian conditions. The total yield of 5,200 kg/ha from cv ICPL-87 far exceeds the higher yields obtained from medium-duration cultivars. Although these experiments were conducted only on Alfisol, it is likely that comparable yields can be obtained on Vertisol. Experiments being carried out in the 1983-84 season should give further information on this point.

This cropping system seems likely to be highly profitable. Although some crop protection with pesticides may be necessary, the short stature of the plants, especially in the case of the determinate cultivars, makes spraying easy to perform. But the high yield potential should amply justify the costs of such sprays.

An additional advantage of this system is that the grain from the first harvest could be sold at a time when prices paid for pigeonpea seed are relatively high. These generally reach a maximum in November, and then fall after the harvest of medium and long duration cultivars, owing to the increased supply on the market (Fig 3).

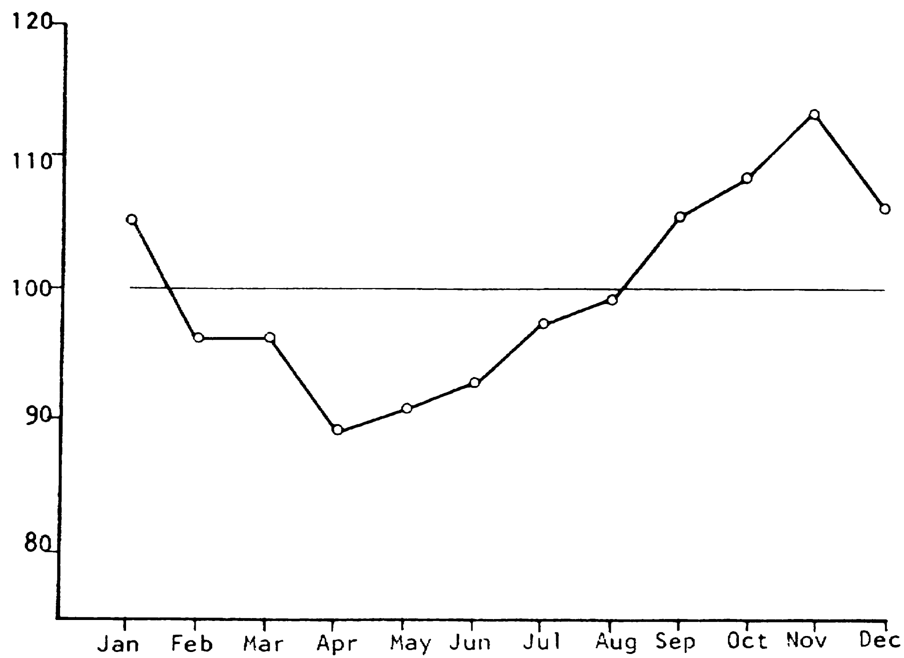


Figure 3. Pigeonpea Seasonal Price Index (on all-India basis) during the period 1970-79 calculated by Dr. T. Walker from Government of India Bulletins on Food Statistics.

III. Response of medium duration cultivar to irrigation given during their reproductive phase

In peninsular India, medium duration cultivars sown in June or July begin to flower in October or November and mature in December. During the period between flowering and maturity little or no rain is received and crop usually grows on conserved soil moisture from the preceding rains. In some years in which rainfall is less, the crop may be seen to be suffering from moisture stress. Similar situations may be encountered when crop is grown on soils with poor water holding capacity such as Alfisols or shallow Vertisols. Some moisture stress is observed even in years in which rainfall is normal. Last year we reported a 23% increase in yield of a sole crop of pigeonpeas grown on Vertisol in response to irrigation given during the reproductive period, even though the year was a high rainfall year (PPR 1981-82, Chapter XII, p.82).

When the yields on Alfisol and Vertisol were compared, in most years lower yields were obtained on Alfisol than on Vertisol, probably due to greater moisture stress in the former (PPR 1981-82 Chapter II p.21). A greater response to irrigation would therefore be expected on Alfisol than on Vertisol. This was examined in experiments this year.

Materials and methods

The experiments were conducted on Alfisol field RP-4B and Vertisol field BP-6. Both fields received a basal dose of 100 kg diammonium phosphate/ha. Three cultivars, C-11, BDN-1, and ICP-1-6 were planted on 75 cm ridges and furrows with 15 cm plant to plant distance (giving 8.8 plants per sq.m) on 22-6-82. In each soil the main plot comprised irrigation treatment and sub plot cultivars. The subplot size was 4.5 x 9 m. There were four replications.

After the commencement of flowering (Table 19), the crop received three irrigations along the furrows. These irrigations on Alfisol field were given on 15-10-82, 19-11-82 and 14-12-82 and on Vertisol on 19-10-82, 20-11-82, and 16-12-82.

Days to maturity of the first flush of pods of different cultivars in two soils are given in Table 19. Harvesting of the first flush was unavoidably delayed by over a month; on Alfisol it was carried out on 24-1-83, and on Vertisol on 4-2-83. At the time of harvest, each subplot was further subdivided into 2 sub-sub plots. The size of the sub-sub plots on Alfisol was 9 sq.m and on Vertisol 7.5 sq.m. The crop was harvested by ratooning in one sub-sub plot and by pod picking in the other. Ratooning was done at about 150 cm above ground level; this enabled pod bearing branches to be harvested leaving the remainder of the plants for ratoon growth. In addition, a 3 sq.m area was harvested completely for the estimation of total dry matter and harvest index. The mean plant stand recorded at the time of first harvest was 8.4 plants/sq.m on Alfisol, close to the theoretical plant population of 8.8, and there were no significant differences due to irrigation among cultivars. On Vertisol the mean plant stand was close to the theoretical population in cvs. BDN-1 (8.0) and C-11 (8.5) but somewhat lower in cultivar ICP-1-6 (6.8).

After the harvest of the first flush one irrigation was given on Alfisol on 21.1.83 and on Vertisol on 8-2-83. On both soils, the second flush matured by 4-4-83 (286 days after sowing) in all cultivars after harvesting the first flush by pod-picking, and by 13-4-83 (295 days) after ratooning. Harvesting was

Table 19. Dates of flowering and maturity of the first flush of pods of 3 medium duration cultivars grown with and without irrigation on Vertisol and Alfisol at ICRISAT Center. Sowing was on 22-6-82 and the number of days after sowing are indicated in parenthesis.

Cultivar	50% flowering		Irrigation	Maturity	
	Vertisol	Alfisol		Vertisol	Alfisol
BDN-1	18-10(118)	12-10(112)	+	23-12(184)	22-12(183)
			-	20-12(181)	17-12(178)
C-11	25-10(125)	28-10(128)	+	30-12(191)	24-12(185)
			-	23-12(184)	20-12(181)
ICP-1-6	31-10(131)	4-11(135)	+	31-12(192)	10-1(204)
			-	26-12(187)	1-12(194)

carried out on these dates, and at this stage the crop was removed completely from the ground.

Results and discussion

Phenology

In previous years we have found that medium duration cultivars generally flower and mature sooner on Alfisol than Vertisol, and that the late rains and/or irrigation tend to delay both flowering and maturity (PPR 1980-81, Chapter III). This year there was less difference between the two soil types than previously observed, although flowering took place about 6 days earlier on Alfisol than Vertisol in cv. BDN-1 (Table 19). Cultivars BDN-1 and C-11 matured a few days sooner on Alfisol than Vertisol, and in all cultivars maturity was delayed by irrigation.

The development of the second flush of pods took place sooner when the first harvest had been taken by pod picking than by ratooning. Although the time to maturity of the second flush was not closely observed, the delay in maturity due to ratooning was at least 9 days. Such delays have been repeatedly observed before, and are largely due to the delayed onset of flowering in the ratooned plants.

Effect on first harvest

Three irrigations given during the reproductive phase increased the seed yield significantly on both Alfisol and Vertisol (Table 20). The extent of the increase was considerably greater on Alfisol (98%) than on Vertisol (19%). Under irrigated conditions the mean yields were similar on both soils, 2100 kg/ha on Vertisol, and 2000 kg/ha on Alfisol. Under unirrigated conditions the yield on Alfisol was only 1000 kg/ha, compared with 1800 kg/ha on Vertisol. The similarity of the yields after irrigation indicates that the large differences between the two soils in yields under unirrigated conditions can by and large be attributed to differences in moisture availability. Large differences in yield on Alfisol due to irrigation were not unexpected as the available water holding capacity of these soils at ICRISAT Center is only about 100 mm. By contrast, the available water holding capacity of Vertisol is around 200-250 mm.

The yields of cvs. BDN-1 and C-11 without irrigation were similar to each other, but with irrigation C-11 outyielded BDN-1 on Vertisol, and BDN-1 outyielded C-11 on Alfisol. In last year's irrigated trial, cv. BDN-1 also yielded better than C-11 on Alfisol, although their yields were similar on Vertisol.

The yield of cv. ICP-1-6 was poorer than that of the other cultivars in all cases.

The method of harvesting the first flush had some influence on the yield recovered on Alfisol. Ratooning gave an average of 250 kg/ha more seed than pod-picking (statistically significant at the 1% level of probability). This effect was not observed in cv. ICP-1-6, but was pronounced in both cv BDN-1 and C-11. The probable reason for this is that in the pod-picking some pods were left on the plants. On Vertisol, by contrast, difference between harvest methods was not significant.

On Vertisol, irrigation resulted in an increase of only 10% in total dry matter at the time of first harvest, but on Alfisol there was an increase of 45% (Table 21). On Vertisol the mean harvest index showed a small, but statistically non-significant, increase from 0.20 to 0.22 as a result of irrigation; but in Alfisol there was an increase from 0.12 to 0.19 in harvest index (statistically significant at the 5% level).

There were no statistically significant effects of irrigation on 100-seed weight on seed number per pod.

The results of this experiment indicate that moisture availability during the reproductive phase may be a major limiting factor for the yield of medium duration pigeonpeas, particularly in Alfisols. Since it is generally not possible to alleviate this stress by irrigation, alternative approaches could include the selection of cultivars which can escape the stress by virtue of their earliness, or which are more tolerant to water stress.

Effect on second harvest

The harvesting of the first flush of pods was delayed by a month and therefore some of the second flush might have been harvested along with the first flush, reducing the yields in the second harvest.

Even with irrigation, the second harvest yields on both soils were relatively low (440 kg/ha). In previous years second harvest yields of over 1 ton/ha have been obtained with irrigation on Alfisol (PPR 1979-80, Table 17) and of over 700 kg/ha on Vertisol (PPR 1981-82, Table 20).

On both soils, irrigation led to a significant increase in second harvest yields (Table 22). This effect was greater on Alfisol (+136%) than on Vertisol (+48%), as would be expected in view of the lower water holding capacity of the Alfisol.

Without irrigation, second harvest yields were higher on Vertisol (295 kg/ha) than Alfisol (185 kg/ha). This is the opposite of the pattern usually observed; second harvest yields are usually less on Vertisol than Alfisol (PPR 1980-81, Chapter VII). We have attempted to account for this difference in terms of the damaging effect of soil cracking in Vertisol in the post-rainy season (PPR 1981-82, Chapter X). This year's results apparently conflict with this interpretation. However, the main difference between this year's results and previous years is that the second harvest yields on Alfisol were unusually low. The yields on Vertisol were actually at a similar level to that observed in previous years. The abnormally low second harvest yields on Alfisol are probably explicable mainly in terms of the delayed first harvest.

In the absence of irrigation, ratooning led to lower second harvest yields than pod-picking on both soils (Table 22). However, at least on Alfisol, part of the higher yield in the pod-picking treatment may be due to a carry-over of pods which were kept on the plants at the time of first harvest, as indicated by the lower first harvest yields obtained by this method (see above). However, with irrigation the ratooned plants yielded as well if not better than those harvested by pod picking on Vertisol (Table 22). On Alfisol there was a clear advantage of pod picking over ratooning only in the case of cv ICP-1-6. In cultivar C-11, the 245 kg/ha yield advantage of the non-ratooned plants may be due to a carry-over of pods, since in this cultivar over 400 kg/ha less yield

Table 20. Effect of irrigation during the reproductive phase on the first harvest yield (kg/ha) of 3 medium duration cultivars grown on Vertisol and Alfisol at ICRISAT Center.

Cultivar	Vertisol			Alfisol		
	Non-irrigated	Irrigated	Mean	Non-irrigated	Irrigated	Mean
BDN-1	1826	2092	1959	1038	2348	1693
C-11	1896	2346	2121	1135	2056	1596
ICP-1-6	1621	1906	1764	874	1630	1252
Mean	1781	2115		1016	2011	

SE (Significance by F test indicated by asterisks)

	Vertisol	Alfisol
Irrigation	41*	90**
Cultivar	56**	191
Irrigation x Cultivar	76	238

Table 21. Effect of irrigation during the reproductive phase on the total dry matter (kg/ha) of 3 medium duration cultivars grown on Vertisol and Alfisol at ICRISAT Center.

Cultivar	Vertisol			Alfisol		
	Non-irrigated	Irrigated	Mean	Non-irrigated	Irrigated	Mean
BDN-1	9400	9020	9210	6010	8720	7360
C-11	8980	9610	9300	6770	10090	8430
ICP-1-6	8610	11170	9890	7270	10160	8720
Mean	9000	9930		6680	9660	

SE (Significance by F test indicated by astericks)

	Vertisol	Alfisol
Irrigation	334	211**
Cultivars	402	643
Irrigation x Cultivars	572	772

was obtained by pod-picking than ratooning, indicating that many pods were left on the plants (not so much by oversight as because they were immature, being part of the second flush).

These results suggest that whereas ratooning may lead to yield reductions in non-irrigated plants, with irrigation it may not have such adverse effects. The conclusion is in conflict with the results obtained last year (PPR 1981-82, Table 2). More light should be shed on this question by experiments being carried out in 1983-84 with extra-early cultivars.

In all cultivars, both seed number per pod and 100-seed weight were less in the second harvest than the first. This effect was particularly pronounced in cv ICP-1-6 where both these components of yield were reduced to a greater extent than in the other cultivars on both soil types (Table 23). Lower seed numbers per pod and 100-seed weights in the second harvest have been observed repeatedly in previous years (see PPR 1981-82, Table 21).

Table 22. Effect of irrigation and method of harvesting the first flush on second harvest yields (kg/ha) of 3 medium duration cultivars grown on Vertisol and Alfisol at ICRISAT Center.

Cultivar	Non-irrigated			Irrigated		
	Pod-picking	Ratooning	Mean	Pod-picking	Ratooning	Mean
			VERTISOL			
BDN-1	607	211	409	306	597	451
C-11	375	273	324	542	600	571
ICP-1-6	192	114	153	302	273	287
Mean	391	199	295	383	490	437
			ALFISOL			
BDN-1	204	110	157	382	436	409
C-11	444	112	278	658	413	535
ICP-1-6	210	32	121	617	119	368
Mean	286	85	185	552	322	437

SE (Significance in F test indicated by asterisks)

	Vertisol	Alfisol
Irrigation	23*	25**
Irrigation x Cultivar	57	50
Irrigation x Harvest method	36**	30
Irrigation x Cultivar x Harvest method	74**	58**

Table 23. Mean 100-seed weight and seed number per pod in first and second harvests from 3 medium duration cultivars grown on Vertisol and Alfisol at ICRISAT Center.

	100 seed weight (g)			
	Vertisol		Alfisol	
Cultivar	First harvest	Second harvest	First harvest	Second harvest
BDN-1	9.6	8.6	10.3	9.1
C-11	10.5	8.8	10.4	8.6
ICP-1-6	10.7	8.6	10.9	8.4
SE +	0.36	0.13	0.25	0.14**
	Seed number per pod			
BDN-1	2.59	2.03	2.28	1.98
C-11	2.85	2.13	2.44	2.17
ICP-1-6	2.41	1.51	2.01	1.30
SE +	0.09*	0.05**	0.11	0.03**

IV. Response to spacing of 10 medium duration genotypes grown in the normal rainy season

In earlier studies we have found that medium duration pigeonpeas showed a remarkable plasticity over a wide range of planting densities on both Alfisol and Vertisol (PPR Chapter V: PPR 1980-81 Chapters II and III). This year we studied the effect of plant density on 10 genotypes of erect, semi-erect and spreading habits in order to assess whether they differ in their response. The experiment was carried out on both Vertisol and Alfisol.

Materials and methods

Experiments were conducted on Alfisol field RP-4C and Vertisol field BP-5. Planting was done on 75 cm ridges and furrows on 8-7-1982 on Alfisol and 9-7-1982 on Vertisol. The genotypes were: HY-8, HY-4 (erect types); ICPL-273, BDN-1 (semi-erect types) C-11, ICPH-2, ICPL-270, PDM-1, LRG-30, and ICP-1-6 (spreading types). These were grown at three plant densities: 44,000, 132,000 and 444,000 plants/ha. The spacing arrangement at the lowest density was 75 x 30 cm with one row on the top of each ridge. The other two densities were arranged at 37.5 x 20 cm and 37.5 x 6 cm spacing with a row on the side of each ridge. The experiments were laid out in a split plot design with cultivars in main plots and spacings in sub plots (4 x 3 m). There were three replications.

Days to 50% flowering and maturity are given in Table 24. Harvesting was carried out from 14 to 17-12-82 except for cv. ICP-1-6 on Alfisol on 31-12-82, and for cvs. C-11 and ICP-1-6 on Vertisol on 31-1-83. The centre 2 ridges of each 4 ridges sub-plot were harvested, and the border rows discarded. Plant populations recorded at maturity are given in Table 25.

There was a high wilt incidence in some plots in both fields and no realistic yield estimate was possible in those plots. The yield in these sub-plots was estimated using missing plot technique; the sub-plots concerned are listed in Table 26.

Results and Discussion

Mean yields on Vertisol and Alfisol

Yield levels were considerably higher on Vertisol (mean yield 1790 kg/ha) than on Alfisol (1010 kg/ha). This difference was probably due to the fact that on Alfisol the plants experienced more severe water stress. In our experiments on the effects of irrigation, which on both soils were carried out in adjacent fields, the mean yields without irrigation were 1780 kg/ha on Vertisol and 1020 kg/ha on Alfisol, which are very similar to the yields in the present experiment. However, with irrigation the yields were 2120 and 2010 kg/ha respectively (Table 20), indicating that the plants on Alfisol without irrigation were much more severely affected by water stress than on Vertisol. The same conclusion is indicated by the earlier maturity of plants on Alfisol than Vertisol (Table 24).

On Vertisol, the highest mean yield (1930 kg/ha) was obtained at the lowest population density of 44,000 plants/ha (Table 27). At 132,000 plants/ha the yield was 7% lower (1802 kg/ha), and at 444,000 plants/ha 16% lower (1630 kg/ha). These results differ somewhat from our previous finding on Vertisol that increasing the population from 44,000 plants/ha to 333,000 plants/ha led to

Table 24. Dates of flowering and maturity of 10 medium duration cultivars grown on Vertisol and Alfisol at ICRISAT Center. (Days after sowing are given in parentheses). Sowing date: 9.7.82 on Vertisol; 8.7.82 on Alfisol.

Cultivar	50% flowering		Maturity	
	Vertisol	Alfisol	Vertisol	Alfisol
HY-4	6-10(86)	27-9(80)	7-12(150)	2-11(116)
HY-8	28-9 (80)	24-9(77)	25-11(138)	*
ICPL-273	21-10(103)	12-10(95)	25-12(168)	14-12(158)
BDN-1	15-10(97)	12-10(95)	15-12(158)	25-11(139)
C-11	1-11(114)	26-10(109)	28-12(171)	*
ICPH-2	21-10(103)	21-10(104)	15-12(158)	*
ICPL-270	21-10(103)	4-10(87)	15-12(158)	16-12(160)
PDM-1	19-10(101)	15-10(98)	15-12(158)	*
LRG-30	31-10(113)	1-11(115)	15-12(158)	14-12(158)
ICP-1-6	3-11(116)	4-11(118)	30-12(173)	19-12(163)

* Date of maturity not recorded owing to premature drying of the plants due to the wilt disease.

Table 25. Plant stand at maturity on Alfisol (A) and Vertisol (V) in different spacing treatments.

Genotype	Soil	Plant population m2		
		4.4[a]	13.2[a]	44.4[a]
HY-4	A	3.9	11.4	34.7
	V	3.7	10.1	29.0
HY-8	A	3.2	8.0	30.7
	V	3.6	9.4	28.8
ICPL-273	A	3.4	10.4	36.4
	V	3.4	11.2	32.4
BDN-1	A	3.9	12.4	38.0
	V	3.9	11.9	37.3
C-11	A	4.2	11.9	37.6
	V	4.2	10.4	35.4
ICPH-2	A	3.6	11.0	37.0
	V	3.6	11.3	33.1
ICPL-270	A	4.2	11.8	34.2
	V	3.8	11.0	35.6
PDM-1	A	3.9	11.3	36.1
	V	4.0	11.3	35.6
LRG-30	A	4.0	12.6	37.1
	V	4.2	11.0	36.2
ICP-1-6	A	3.7	11.9	34.9
	V	3.[illegible]	9.9	30.8

SE for Vertisol 1.1 SE for Alfisol 1.1

[a]Theoretical population.

Table 26. Subplots estimated by missing plot analysis

Alfisol			Vertisol		
Cultivar	Replication	Plant population/m^2 (theoretical)	Cultivar	Replication	Plant population/m^2 (theoretical)
HY-8	2	44.4	HY-4	1	4.4
C-11	2	4.4	ICPH-2	1	4.4
ICPH-2	2	4.4	PDM-1	1	4.4
PDM-1	2	13.2	LRG-30	1	44.4
LRG-30	2	4.4	LRG-30	3	13.2
ICPH-2	3	4.4	LRG-30	3	44.4

a slight increase in yield (PPR 1979-80, Fig.6). However, once again they demonstrate the remarkable plasticity of pigeonpeas over a wide range of population densities.

On Alfisol, as on Vertisol, the highest mean yield (1270 kg/ha) was obtained at the lowest plant population. At 132,000 plants/ha the yield was 16% lower (1060 kg/ha) and at 444,000 plants/ha 46% lower (682 kg/ha)(Table 28). These results differ from previous results on Alfisol, where the optimum population density was around 150,000 plants/ha (PPR 1979-80, Fig.7). One reason for the difference between the two years might be that in 1979-80 there was about 80 mm rainfall in November, during the reproductive phase (PPR 1979-80, Fig.1) whereas this year there was only 12 mm rainfall in November (Fig.1). Hence the plants may have been subjected to a more severe moisture stress this year, which would have been more pronounced at high population densities.

In our 1979-80 experiment, and also in the previous year (PPR 1978-79, Table 28) increasing the plant population above 44,000 plants/ha led to a progressively greater production of total dry matter, and we suggested that this might be of economic value in producing more firewood. This year also, on both soils more total dry matter was produced at the highest population density than at the lowest (Table 29 fig.4), but the increase was small (only 6% in both cases). Since the yield declined significantly at this population density, there would have been an economic disadvantage with high plant populations this year.

Components of yield

There were no significant spacing x cultivar interactions for harvest index. On both soils this declined as the population density increased (Table 29), as is apparent with our previous results (e.g. PPR 1979-80, Fig.8).

Cultivar x spacing interactions were also not significant for 100-seed weight or seed number per pod. There was a tendency for 100 seed weight to decline as the plant population increased (Table 29). Pod number per plant, of course, declined steeply at the higher population densities (Table 29).

Cultivaral differences

One of the purposes in conducting this trial was to find out if certain cultivars, especially the more erect types, would give more yield at higher population densities. We could find little evidence to support this idea. On both soils, the yields of the erect cvs HY-4 and HY-8 were not significantly affected by planting density (Tables 27 and 28), and the semi-spreading cultivars ICPL-273 and BDN-1 gave lower yields as the planting density was increased.

The highest yielding cultivars on Vertisol were C-11 and BDN-1 (Table 27). On Alfisol cv. HY-4 gave the highest mean yield (Table 28). However, at the optimum population of 44,000 plants/ha, it was outyielded by 5 other cultivars, the best of which, cv LRG-30, gave 30% more. The reason why cv. HY-4 had the highest mean yield was that its yield was not depressed in the denser plantings, as it was in all other cultivars except cv. HY-8. The reason why these two more erect cultivars were able to perform relatively at high population densities is, however, less likely to be connected with their shape than with

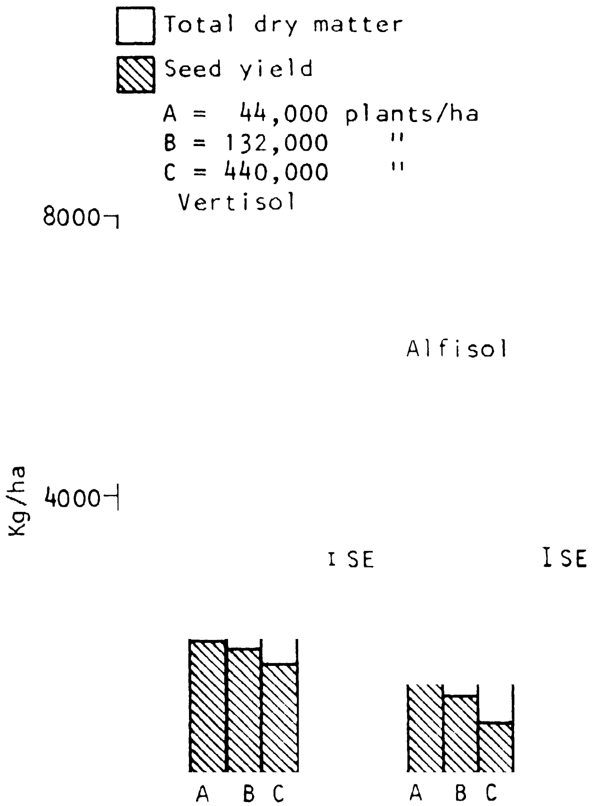


Figure 4. Effect of planting density on yield and total dry matter (kg/ha) on Vertisol and Alfisol.

Table 27. Effect of plant population on yield (kg/ha) of 10 cultivars grown on Vertisol at ICRISAT Center.

Genotype	Yield (kg/ha) Population (plants/ha) 44,000	132,000	444,000	Mean
HY-4	1782	1724	1603	1703
HY-8	1205	1493	1284	1327
ICPL-273	1657	1438	1412	1502
BDN-1	2333	1829	1680	1947
C-11	2184	2204	1907	2099
ICPH-2	1889	1835	1519	1748
ICPL-270	2122	2045	1591	1920
PDM-1	2044	1651	1621	1772
LRG-30	1899	1967	1909	1925
ICP-1-6	2184	1836	1756	1926
Mean	1930	1802	1628	
SE				
Cultivar	114.5**			
Spacing	42.1**			
Cultivar x spacing	157.3			
Except when comparing means within a cultivar	133.3			

Table 26. Effect of plant population on yield (kg/ha) of 10 cultivars grown on Alfisol at ICRISAT Center.

Cultivar	Yield (kg/ha) Population (plants/ha) 44,000	132,000	444,000	Mean
HY-4	1310	1507	1151	1323
HY-8	572	607	709	629
ICPL-273	1048	866	519	811
BDN-1	1292	1273	944	1170
C-11	1332	1039	522	964
ICPH-2	1501	1054	486	1014
ICPL-270	1456	1397	608	1154
PDM-1	871	439	664	658
LRG-30	1709	1022	513	1081
ICP-1-6	1615	1438	698	1250
Mean	1271	1064	682	

SE	
Cultivar	121.4**
Spacing	52.7**
Cultivar x Spacing	182.5*
Except when comparing means within a cultivar	166.8*

Table 29. Effects of plant population on mean harvest data for 10 medium duration cultivars grown in the normal season at ICRISAT Center on Vertisol and Alfisol.

	Vertisol Plants/m²				Alfisol Plants/m²			
	4.4	13.2	44.4	SE	4.4	13.2	44.4	SE
Total dry matter (kg/ha)	7336	7283	7779	149*	4959	5506	5278	220
Harvest index	0.25	0.24	0.21	0.01**	0.23	0.19	0.13	0.007**
100-seed weight (g)	9.13	8.98	8.58	0.17*	8.29	8.45	7.97	0.25
Seeds/pod	2.82	2.75	2.96	0.07	2.51	2.52	2.41	0.07
Pods/plant	187	67	19	4.5**	145	44	9	2.7**

Table 30. Effects of plant population on primary and secondary branch number (at the time of harvest) in 10 medium duration cultivars grown on Vertisol and Alfisol at ICRISAT Center.

Cultivar	Primary branches per plant			Secondary branches per plant		
Plants/m^2	4.4	13.2	44.4	4.4	13.2	44.4
VERTISOL						
HY-4	11	9	8	14	5	2
HY-8	11	9	7	18	8	5
ICPL-273	15	15	9	34	11	2
BDN-1	13	11	8	26	9	1
C-11	25	24	17	48	27	6
ICPH-2	24	21	15	48	21	5
ICPL-270	14	15	9	34	16	3
PDM-1	24	19	14	59	17	5
LRG-30	22	22	17	44	23	4
ICP-1-6	25	22	14	47	18	4
Mean	18	17	12	37	16	
ALFISOL						
HY-4	10	10	6	9	3	0
HY-8	11	8	5	9	4	2
ICPL-273	15	14	8	26	6	2
BDN-1	13	11	10	22	7	1
C-11	20	18	18	63	22	3
ICPH-2	18	19	13	32	13	3
ICPL-270	13	13	13	25	10	2
PDM-1	17	14	10	34	6	3
LRG-30	22	20	10	35	14	1
ICP-1-6	21	21	15	35	17	2
Mean	16	15	11	29	10	2

SE		Primary branches	Secondary branches
Spacing	Vertisol	0.4**	1.2**
	Alfisol	0.4**	1.2**
Cultivar x Spacing	Vertisol	1.5	3.7**
	Alfisol	1.9**	3.5**

the fact that they were both considerably earlier than all the other cultivars. On Alfisol, cv. HY-4, for example, flowered 15 days sooner than cv. BDN-1, and matured 23 days earlier (Table 24). This means that they probably escaped the more severe effects of moisture stress.

In some cultivars the yields on Alfisol were exceptionally poor - Cv. PDM-1 for example, gave a mean yield of 1770 kg/ha on Vertisol, and only 660 kg/ha on Alfisol. However, this does mainly reflects the much higher incidence of the wilt disease in this cultivar on Alfisol, when in most plots about half the plants died; in Vertisol, by contrast, there was little mortality.

In relation to total dry matter, there were no significant interactions between cultivars and population density on either type of soil.

However, in the effect of population density on branching there were significant differences in the reactions of the different cultivars (Table 30). On both soils, increasing the population density had a relatively small effect on suppressing primary branching, presumably because most primary branches develop at an early stage, before plant-to-plant competition has had much effect. However, secondary branching was markedly suppressed as the plant population increased on both soils (Table 30). This happened more in some cultivars than others : cv. PDM-1, for example, showed a more marked decline at 132,000 plants/ha on both soils than cv. C-11.

There were clear differences among cultivars in the numbers of primary and secondary branches, with the least in cvs. HY-4 and HY-8, an intermediate number in the semi-spreading cvs. ICPL-273 and BDN-1, and most in cvs. C-11, ICPH-2, PDM-1 and ICP-1-6 (Table 30).

V. Effect of plant density and irrigation on postrainy season pigeonpea

A positive response to two or three irrigations (PPR 1978-79, Table 55; PPR 1979-80, Table 27; PPR 1980-81, Table 24) and increasing plant density (PPR 1977-78, Table 66; PPR 1980-81, Table 28) in post rainy season pigeonpea has been reported earlier. The response to both these factors, however, was studied in separate experiments. It was not clear from these studies whether there would be an interaction between these two factors. To study this aspect an experiment was conducted this year with two cultivars, C-11 and AS-71-37, which have given consistently good yields in the post rainy season at Patancheru (PPR 1980-81, Section X).

Materials and Methods

The experiment was conducted in Vertisol field BP-3A which was kept fallow during rainy season. Sowing was done on flat seed beds on 31-10-83. The design of the trial was a split plot with 3 replications. Irrigation and no irrigation treatments comprised main plot and cultivars (C-11 and AS-71-37) in 4 plant density treatments were randomised in a factorial design in subplots. The densities were 100, 67, 42, and 25 plants per sq.m which were obtained by planting at 20 x 5, 25 x 6, 30 x 8, and 40 x 10 cm spacing arrangements respectively. The size of each subplot was 6 x 4 m. Irrigation was not necessary to germinate the seeds as there was rain just after sowing. Three irrigations were given on 26-11-82, 27-12-82, and 9-2-83 which coincided with early vegetative, late vegetative and reproductive phase of the crop respectively. Irrigations were given using perfo system.

Dates of 50% flowering and maturity and harvest are given in Table 31. Plant stands counted at harvest are given in Table 32. These were not significantly affected by irrigation, nor were there significant differences between cultivars. The actual populations were about 30% below the theoretical at the highest density, about 20% below at 67 plant/sqm, about 15% below at 42 plants/sqm, and only 8% below at the lowest density.

At harvest a 10.8 to 11.4 sq.m area was harvested for determining yield and total drymatter. Yield components, seed number per pod and 100 seed weight were recorded from a 20 plant subsample from each subplot. Pod number per plant was calculated from whole plot yields on the basis of seed number per pod and 100 seed weights determined in the subsamples.

Table 31. Dates of flowering, maturity and harvest of two pigeonpea cultivars sown on 31-10-82, at ICRISAT Center and grown either without irrigation or with irrigation on 26-11-82, 27-12-82, and 9-2-83. (Days after sowing are given in parentheses).

Cultivar	Irrigation	50% flowering	Maturity	Harvest
AS-71-37	+	10-1-83 (71)	8-3-83 (128)	9-3-83
	-	10-1-83 (71)	23-2-83 (115)	2-3-83
C-11	+	14-1-83 (75)	8-3-83 (128)	9-3-83
	-	14-1-83 (75)	25-2-83 (117)	2-3-83

Table 32. Effect of irrigation and planting density on plant population at the time of harvest of two cultivars grown in the post-rainy season at ICRISAT Center.

Theoretical population/m^2	Plant number/m^2					
	Irrigated			Non-irrigated		
	C-11	AS-71-37	Mean	C-11	AS-71-37	Mean
100	64	79	71	72	71	72
67	60	52	56	56	49	53
42	37	33	35	39	34	36
25	25	21	23	24	22	23
Mean	46	46		48	44	
	46			46		

SE	
Irrigation	1.5
Irrigation x Cultivar	1.8
Irrigation x Spacing	2.2
Irrigation x Cultivar x Spacing	2.9

Results and Discussion

Phenology

Flowering occurred at 75 days after sowing in cv. C-11 and 71 days in cultivar AS-71-37 in both irrigated and unirrigated treatment (Table 31). However, maturity occurred earlier in unirrigated treatments in both cultivars apparently due to moisture stress. A similar effect has been observed before (PPR 1981-82, Table 22).

The length of the reproductive period in two cultivars was more or less similar.

Growth and Yield

Irrigation increased the mean yield by 90%, from 800 to 1520 kg/ha (Table 33), and total dry matter by 70%, from 1920 kg/ha to 3260 kg/ha (Table 34). This large response to irrigation confirms our previous findings with post-rainy season pigeonpeas (PPR 1978-79, Table 55; PPR 1979-80, Table 27; PPR 1980-81, Table 24) and indicates that the yields of pigeonpeas grown without irrigation in this season are severely limited by moisture stress.

Both with and without irrigation, cv. C-11 outyielded cv. AS-71-37; its mean yield was 14% higher (Table 33) Cv. C-11 also produced more total dry matter (Table 34). This contrasts with a previous trial in which cv. AS-71-37 grew and yielded more than cv. C-11 (PPR 1980-81, Table 33). The difference between the two cultivars cannot be accounted for in terms of plant stand, since this was similar in both cases (Table 34).

Against our expectations, there was no significant interaction between irrigation and plant population for yield or total dry matter (Tables 33 and 34). Both with and without irrigation most yields and dry matter were produced at 670,000 plants/ha. However, these were only slightly different from the yield and dry matter production at 1,000,000 and 420,000 plants/ha. The lowest population, 250,000 plants/ha, gave significantly less yield and total dry matter (Tables 33 and 34) and was therefore somewhat sub-optimal.

Previous experiments have shown that in the post-rainy season there is a broad population optimum in the range from 250,000 to 500,000 plants/ha (PPR 1980-81, Chapter IX). This year's results show a slightly higher optimum, but confirm that there is a broad plateau, indicating that the plants have a striking ability to adjust to a wide range of densities. Taking all the results together, a population of about 500,000 plants/ha, for example with a 30 x 7 cm spacing, would seem to be about optimal under Hyderabad conditions, with or without irrigation (Fig.5).

Yield components

Irrigation resulted in a higher harvest index (0.47 compared with 0.42), as observed previously (PPR 1977-80, Table 31, PPR 1980-81, Table 25). It had no significant effect on seed number per pod but resulted in a somewhat higher 100-seed weight (Table 35). As usual, the most important component of yield that was affected by the treatment was pod number per plant.

Table 33. Effect of Irrigation and Plant Population on yield (kg/ha) of two pigeonpea cultivars grown in the post rainy season at ICRISAT Center.

	Yield (kg/ha)					
	Irrigated			Non-irrigated		
Plant Population/ha	C-11	AS-71-37	Mean	C-11	AS-71-37	Mean
1,000,000	1629	1441	1535	955	707	831
670,000	1698	1592	1645	940	750	845
420,000	1649	1470	1560	768	712	740
250,000	1433	1228	1330	784	784	784
Mean	1602	1433		862	738	
Mean	1517			800		
	Cultivar x Spacings					
1,000,000	1292	1074	1183			
670,000	1319	1171	1245			
420,000	1209	1091	1150			
250,000	1108	1006	1057			
Mean	1232	1085				

SE

Irrigation	91*
Cultivar	31*
Spacing	43
Irrigation x cultivar	96
Irrigation x spacing	105
Cultivar x spacing	61
Irrigation x cultivar x spacing	122

Table 34. Effect of Irrigation and Plant Population on total dry matter (kg/ha) in two pigeonpea cultivars grown in the post rainy season at ICRISAT Center.

	Total Dry Matter (Kg/ha)					
	Irrigated			Non-irrigated		
Plant Population/ha	C-11	AS-71-37	Mean	C-11	AS-71-37	Mean
1,000,000	3730	3056	3393	2312	1739	2026
670,000	3878	3324	3601	2331	1857	2094
420,000	3591	3106	3348	1850	1642	1746
250,000	2939	2464	2701	1815	1831	1823
Mean	3534	2987		2077	1767	
Mean	3261			1922		

	Cultivars x Spacings		
1,000,000	3021	2397	2709
670,000	3105	2591	2848
420,000	2720	2374	2547
250,000	2377	2148	2262
Mean	2806	2377	

SE	
Irrigation	109**
Cultivar	71**
Spacing	100**
Irrigation x cultivar	130
Irrigation x spacing	164
Cultivar x spacing	141
Irrigation x cultivar x spacing	217

There was a decline in harvest index at higher population densities, and a significant decline in 100-seed weight (Table 36). Similar trends have been observed in previous experiments (PPR 1976-77, Tables 61 and 63; PPR 1977-78, Tables 68 and 71; PPR 1978-79, Tables 48 and 49; PPR 1980-81, Fig.22).

Table 35. Effect of irrigation on harvest index and yield components of 2 cultivars grown in the post-rainy season at ICRISAT Center.

	rrigation	No irrigation	SE
Harvest index	0.47	0.42	0.014
Pod no/plant	20	12	1.0*
Seed no/pod	2.54	2.49	0.09
100-seed weight	7.80	7.24	0.16

* Significant (F test)

Table 36. Effect of plant density on harvest index and yield components of two cultivars grown in the post rainy season at ICRISAT Center.

	Plant population/ha				
	1,000,000	670,000	420,000	250,000	SE
Harvest index	0.43	0.43	0.45	0.46	0.009
Pod No/Plant	9	13	17	24	0.9**
Seed No/Pod	2.54	2.54	2.50	2.48	0.06
100-seed weight	7.32	7.31	7.45	7.99	0.18*

*, ** Significant (F test)

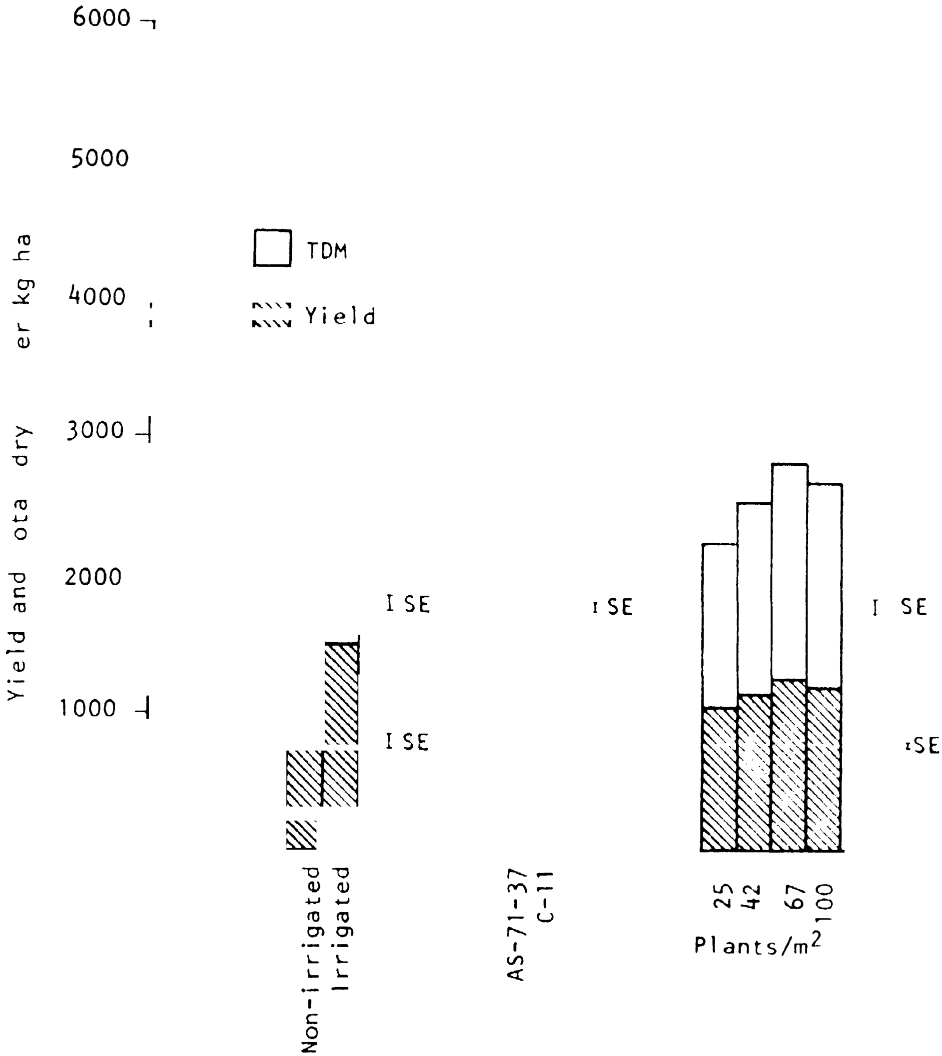


Figure 5. Yield and total dry matter of two cultivars grown with and without irrigation at four plant populations in post-rainy season.

VI. Effect of temperature on flowering and podset in pigeonpeas

There is a wide range of maturity types available in pigeonpea. When planted around longest day, early cultivars mature before the cool period from November to February, medium cultivars adapted to peninsular India flower and set pods during the cool period, while the late cultivars adapted to north India mature after the winter when temperatures begin to rise. Last year we hypothesized that one of the reasons for low yields of medium duration pigeonpeas may be that their flowering and pod set occurred during winter (PPR 1981-82, Chapter II). Low night temperatures might be inhibiting pod set in these cultivars. In other crops, such as soybeans it is known that low night temperatures can reduce or prevent pod set. In pigeoneas the existence of a critical temperature for leaf initiation of around 16°C has been suggested by studies in contolled environments. But so far there have been no experimental investigations on critical temperatures for pod set in pigeonpeas. We conducted some preliminary experiments to investigate this point.

Materials and Methods

Pot Experiment

Cultivar ICPL-87, a short duration determinate cultivar was planted in 6" pots using Vertisol on 19.1.83, and a single plant was raised in each pot in screen house. These pots received irrigation as and when necessary. There were four night temperature treatments 7 , 15 , 25 , (in laboratory) and 25°C (in screen house). There were six replicated pots per treatment. These treatments were imposed on 14.3.83, soon after flowering, which occurred 50-55 days after sowing. The plants were synchronised for flowering by removing already developed flowers. Plants in first two treatments (7 and 15°C) were kept in large incubators every night between 1645 and 0815 hrs. On Sundays, (20-3-83, 27-3-83 and 3-4-83) plants remained inside the incubators all day. Plants in third treatment were kept inside the laboratory between 1645 and 0815 hours every night, where night temperatures were around 25°C. During the day time (between 0815 and 1645 hrs) plants in all the above three treatments were kept outdoors except on Sundays. Plants in the fourth treatment remained in the screen house continuously, where minimum temperatures at night were around 25°C. Temperatures experienced by plants in different treatments at various times are given in Fig.6.

Counting of flowers developing in different treatments was done from 17.3.83 onwards at about 2-day interval by marking them with different colors (to exclude the possibility of duplicate counting). Treatments were continued for 20 days by which time flowering in all treatments was nearly complete except in the 7°C night temperature treatment. At this stage pod number and leaf number per plant were also counted.

Results and discussion

The most interesting feature of this experiment was the absence of pod set in the plants kept in night temperatures of 7°C, while pod set occurred normally at night temperatures of 15 and 25°C (Fig 6). This suggests that there was a critical temperature for pod set in this cultivar somewhere between 7 and 15°C. Further experiments will be necessary to identify this temperature, to find out the effects of different periods of exposure to cool nights, and to investigate cultivar differences in this respect. Circumstantial evidence from field

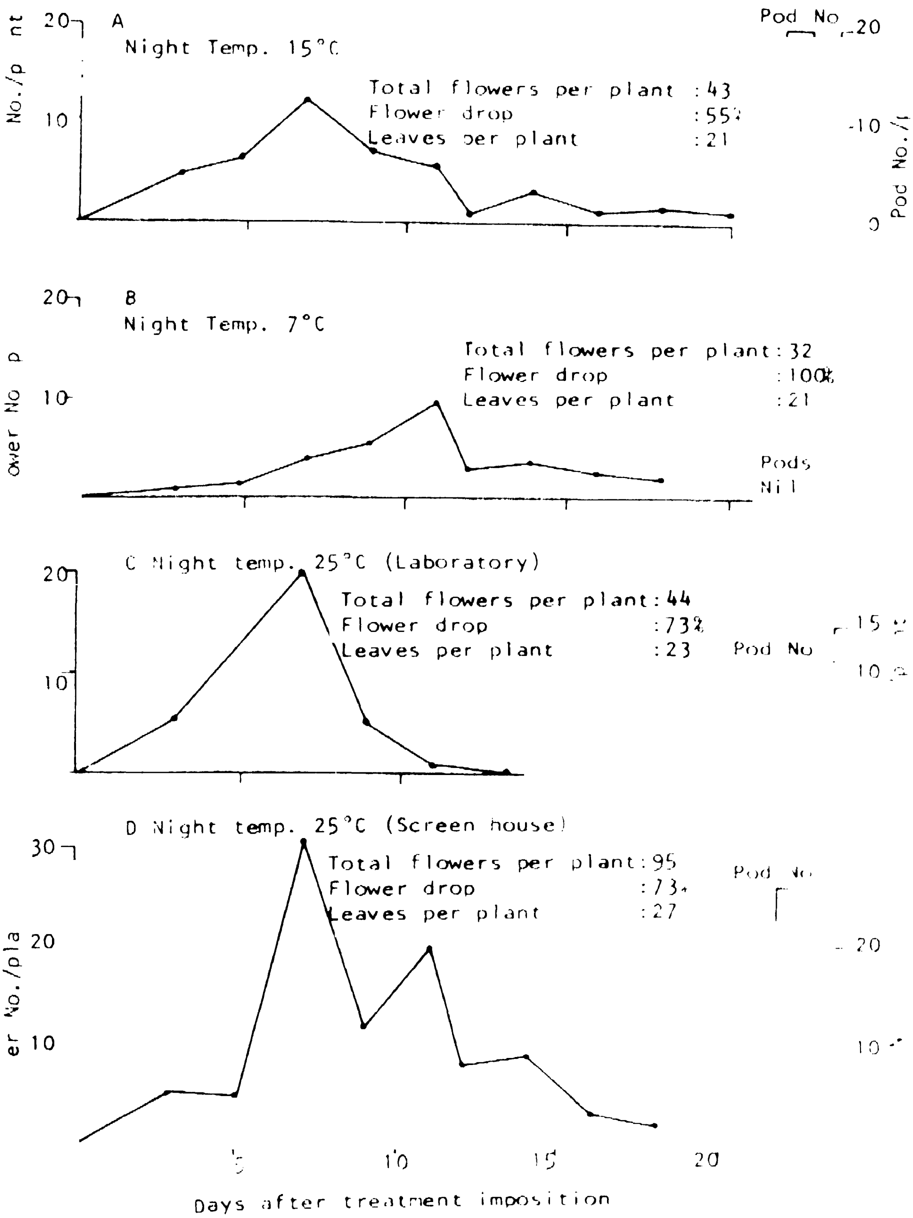


Figure 5. Effect of night temperatures on pod set.
A & B plants kept in incubators,
C: Plants kept indoors in lab. and
D: Plants kept in screenhouse during night.

observations at Gwalior suggests that some late cultivars, notably Bahar, may be able to set pods at lower temperatures than most medium duration cultivars (see Chapter 7).

The maximum numbers of flowers and pods were produced by the plants kept continuously in the screen house (Fig 6, treatment D) and these plants also had more leaves (27 per plant) than in the other treatments. A major reason for the better performance of these plants is probably that they were exposed to about 4 hours more light per day than the other plants, which were moved indoors at 4.45 pm, and put outdoors into the daylight at 8.15 am.

Plants kept at night temperatures of 15°C in incubators and at 25°C in the laboratory produced similar numbers of flowers and leaves, but flowering was spread over a longer period at 15°C, and more pods were set.

Night temperatures of 7°C had little effect on the number of leaves per plant, but led to fewer flowers being produced and also to a prolongation of the flowering period. The fact that flowering continued while pod set was prevented shows that pod set is more sensitive to cool nights than flower development. This is in agreement with field observations at Gwalior, where some flowering takes place during the cool winter period, but there were little or no pod set (see Chapter 7).

VII. Some preliminary observations on the effect of low termperatures on pod set under north Indian conditions

Late maturing pigeonpeas grown in northern India generally start flowering in late November or December, before the coldest part of the year, and flowering continues (although rather sparsely); but little pod set takes place until the weather becomes warmer, in late January or February. Thus low temperatures seem to be directly or indirectly responsible for the failure of pod set. Such inhibitory effects of low temperatures on pod set are known to occur in other legumes, including soybeans and chickpeas.

Observations were made on pigeonpea in ICRISAT trials at Gwalior on a visit from February 20 to 22, and data were also supplied by Mr. M.D. Gupta.

In one trial planted in early July, various long duration cultivars reached 50% flowering between November 24 and December 22. Some pods were set soon after flowering especially in those cultivars which began flowering in late November or early December. Thereafter, for about a month, there was very little pod set, and flowers were shed from the plants. Pod set began again in late January or early February. When the plants were examined on February 21, they were bearing both dried mature pods and developing pods. In some cases, both were present on the same racemes, but they were separated by a series of scars left by the abscission of flowers after the first phase of pod set, and before the second.

A range of cultivars was scored visually on February 21 for the number of dry mature pods, and for maturing green pods, large young pods and small young pods. The latter would probably have set during the preceding week or [illegible], the large young pods from 1-2 1/2 weeks before, and the maturing pods from about 2 1/2 - 4 weeks before. These scores are shown in Table 37, together with the dates of 50% flowering.

The plants were scored without knowing the dates of 50% flowering so as to avoid any unconscious bias. From Table 37, it is clear that the number of dry mature pods tended to be greater in the cultivars which flowered earlier, and less in those that flowered later. This is probably because the earlier flowering cultivars had a longer period, before the onset of weather too cold for pod setting.

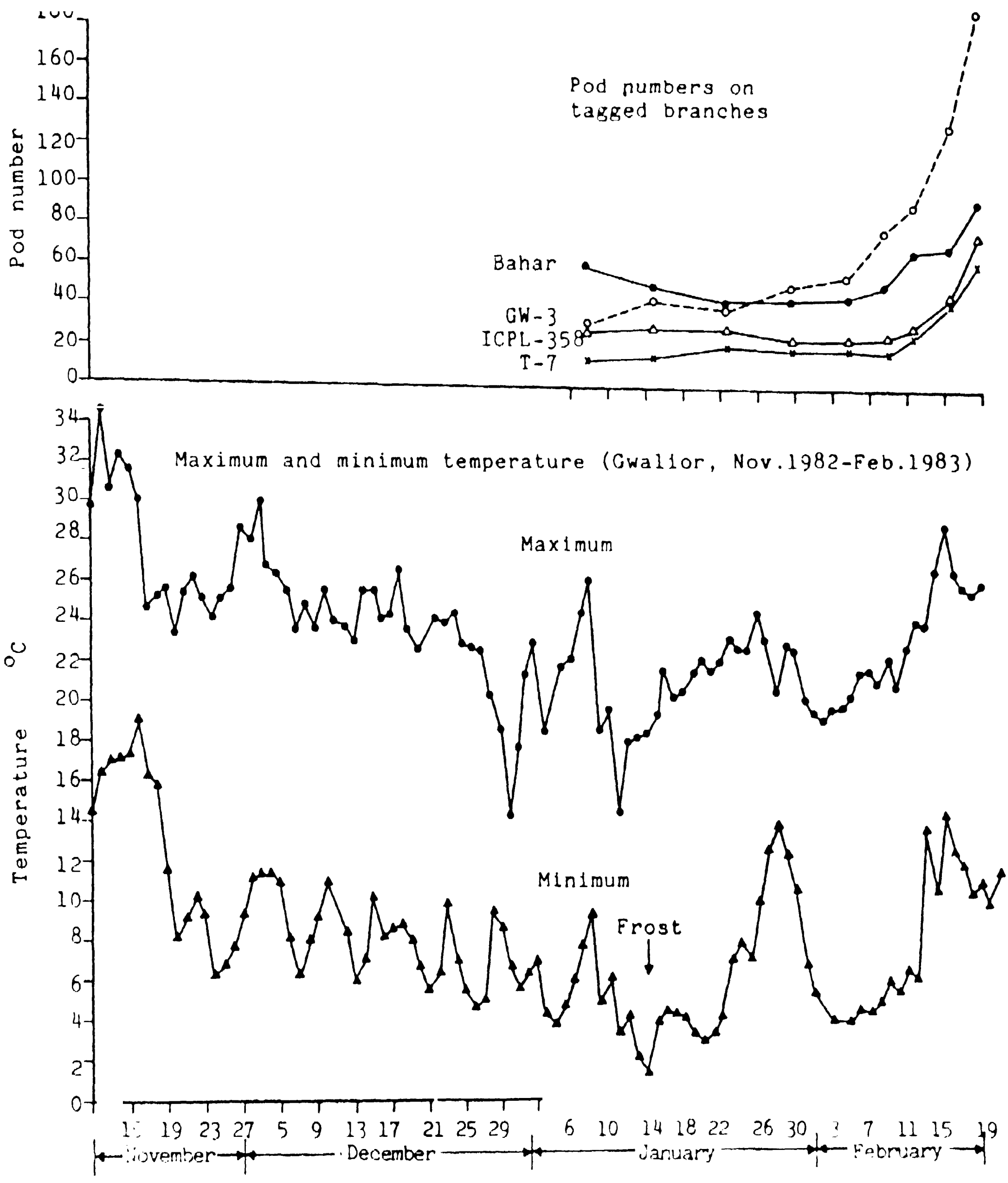
The daily temperature data for Gwalior are shown in Figure 7. Both maximum and minimum temperatures showed a declining trend throughout December and the first half of January. The fact that cultivars which reached 50% flowering after December 14th had few mature pods indicates that temperatures from around this date onwards were generally unfavourable for pod set. From Figure 7, it can be seen that from mid-December minimum temperatures were below 10 °C, and on several nights in late December below 6 °C. In mid-January on one night the air temperature, fell to 1.4 °C, and there was in fact a mild frost.

However, the fact that there were quite a number of mature pods on plants which began flowering in late November or early December shows that pod setting occurred under the temperature conditions prevailing in the first half of December. Maximum temperatures in this period were 24 °C or above, and minimum

Table 37. Relative quantities of pods at different stages of maturity on a range of late cultivars at Gwalior on February 21, 1983.

Cultivar	Date of 50% flowering	Dry mature pods	Maturing pods	Large young pods	Small young pods
73081	Nov 24	+++	++	+	+
GW-3	Nov 30	+++	+++	+++	+++
Bahar	Dec 1	+++	++++	+++	+
ICP-7041	Dec 2	++	+	+	+
T-7	Dec 7	++	++++	++++	+++
ICPL-310	Dec 8	+++	+++	++	++
73100	Dec 10	++	++	++	++
ICPL-311	Dec 11	++	+++	++	++
ICPL-362	Dec 14	+	+++	+++	++
ICPL-358	Dec 17	+	+	++	+++
T-17	Dec 20	+	++	++++	+++
NP(WR)-15	Dec 22	+	+	+++	+++

Figure 7. Daily maximum and minimum temperatures at Gwalior, winter 1982-83, and pod set on tagged branches of four late cultivars planted in July 1982.



temperatures ranged between 6 and 11 °C.

The presence of maturing pods on the plants on February 21 which were probably about a month old suggests that pod set began again in late January. In this period maximum temperatures were mostly around 23 °C, and minimum temperatures rose to 14 °C, although they fell again to as low as 4 °C in early February.

Regular observations on the number of pods on a few tagged branches by Mr. Gupta and his staff showed that these increased rapidly from about February 12 onwards, when the minimum temperature rose above 10 °C and the maximum above 24 °C (Figure 7). However, some rise in pod numbers occurred before this, possibly as a result of pod set during the relatively warm period in late January.

Taken together, these observations suggest that pod set in late cultivars can take place when maximum temperatures are about 24 °C and minimum temperatures above about 8-10 °C, but that it is inhibited when minimum temperatures fall below about 6 °C with maximum temperatures less than about 22 °C.

It seems likely that there are differences between late cultivars in their tolerance of low temperatures. The relatively great numbers maturing and large green pods on plants of cultivars such as Bahar and T-7 (Table 37) suggest that they were better able to set pods in the cool weather in late January and early February than cultivars such as ICP-7041 and ICPL-358.

Even greater genotypic differences may exist in temperature tolerance between late and medium cultivars. In a monthly planting trial, the medium cv. C-11 planted in July reached 50% flowering on November 14, and had set considerable numbers of pods before the onset of the cold weather. However, although flowering on these plants was still continuing when they were observed on February 21, few new pods were developing.

In the August planting, cv. C-11 reached 50% flowering on 29 November; but the plants had very few dry mature pods, indicating that little pod set had occurred in December, by contrast with July-planted late cultivars which began flowering around the same time (Table 37). In the same August planting, the late cv. Bahar reached 50% flowering on December 18, three weeks later than cv. C-11. When the plants were observed on February 21, cv. Bahar had considerable numbers of maturing pods and young pods, indicating that pod set begun only about 7-10 days ago, when the maximum temperatures had risen to over 24 °C and the minimum to over 10 °C (Figure 7).

Since late cultivars have been grown for centuries under conditions in which they are exposed to cold winter weather, there may have been natural selection for cold tolerance. Medium cultivars have not been subject to such selection and may therefore be more sensitive to cold. However, even medium cultivars are subjected to cool weather during their respective phase - at Hyderabad, for example, minimum temperatures are not infrequently below 10 °C when they are flowering and podding in November and December. It seems possible that pod set could be increased in medium cultivars in Hyderabad-type environments if they were more tolerant to cool conditions. One way this might be achieved is by selecting among medium cultivars for cold tolerance. Another way might be to introduce cold tolerance into medium lines by crossing with cold-tolerant late cultivars, examples of which may be cvs. T-7, Bahar, and GW-3. In any case, it seems to be worth looking for genotypic differences in cold tolerance in a range of medium and late cultivars.

VIII. Compensatory ability of pigeonpea

The flowers and pods of pigeonpeas are often subjected to heavy attack by insect pests such as the pod borer, *Heliothis armigera*. The plants' ability to compensate for the loss of flowers and pods has been investigated over the past several years (PPR 1975-76, Chapter II, PPR 1976-77, Chapter II, PPR 1977-78, Chapter III). It was found that while plants were capable of compensating for the removal of flowers or very young pods more or less completely, their ability to compensate for damage to developing pods was very limited (PPR 1977-8, Chapter III; PPR 1978-79, Chapter III and PPR 1980-81, Chapter XI). This suggested that the remaining parts of the damaged pods may have had some inhibitory effect on the development of further pods, which was not entirely explicable in terms of the total amount of assimilates they consumed. Such an effect could be related to hormones released by the remaining parts of the damaged pods inhibiting the development of new pods. It was hypothesized that greater compensatory ability should be observed when pods are removed completely than when parts of pods are removed. The hypothesis was examined with three cultivars this year. One of these cultivars, APAU-2208, has been identified by ICRISAT Pulse Entomologists as having an unusual ability to compensate after damage by insect pests.

Two methods of pod damage were employed: one involved clipping off the distal half of the young pods with scissors, as in previous experiments; the other involved stapling them. The metal staple usually punctured two locules, resulting in seed abortion, and since the staple remained in the pod it made the treated pods easy to identify. We hoped that this stapling technique would simulate more closely the damage due to the pod borer, *Heliothis armigera*, and other pests than the pod clipping treatment.

Materials and methods

The experiment was conducted in Alfisol field RP-4B. Three cultivars, ICP-1, HY-3A and APAU-2208 were planted on 7-7-1982 on the top of 75 cm ridges at 75 x 10 cm spacing. The plot size was fairly large (108 sq.m). There were four replications. The first replication was adjacent to an irrigation experiment, and owing to seepage of water, the plants in this replication grew better and yielded more than the rest. To avoid this confounding effect, this replication was dropped from the statistical analysis, and the results given below are based on 3 replications only.

Each plot was subdivided into 5 sub plots (4 x 3 m) for imposition of following 5 treatments:

T1. Control

T2. 1/2 pod clipping (the distal part of each young pod [illegible] [illegible])

T3. 50% pod removal (about half the number of pods were removed from each raceme and branch)

T4. 100% pod removal (all the pods were removed)

T5. 50% seed abortion (all the young pods were stapled using metal staple pins. These pierced two locules and caused the seeds in them to abort).

Cvs. ICP-1, APAU-2208 and HY-3A reached 50% flowering on 25-10-82 28-10-82, and 31-10-82 respectively. The above mentioned treatments were imposed about 10-14 days after 50% flowering for the first time and again 8 to 12 days after this as per the schedule given in Table 38. Pods removed in T3 and T4 treatments were counted.

When observed on 13-12-82, most of the pods had matured in T1 in all cultivars, whereas in the remaining treatments maturity occurred later. Cultivars ICP-1, APAU-2208 and HY-3A matured on 15-12-82, 25-12-82, and 20-12-82 respectively except in T4. Cultivar ICP-1 was harvested on 21-12-82, APAU-2208 on 3-1-83 and HY-3A on 23-12-82 in all treatments except in T4. T4 in ICP-1 APAU-2208 and HY-3A matured on 30-12-82, 3-1-83 and 30-12-82 respectively and harvesting was carried out on these days.

Harvesting of these cultivars was done row wise. From pod clipping and stapling treatments, treated and untreated pods were separated to get an idea of effect of pod clipping and stapling on seed number per pod of treated and untreated pods. However, the data were then pooled to get an overall picture of compensation. From each row all the seeds and pods were counted for the determination of seed number per pod and 100-seed weight.

Results and Discussion

Pod removal

The removal of all the young pods from the plants during the early reproductive phase soon led to the setting of more pods from later-formed flowers than would otherwise have set. These pods were again removed 8-12 days later. The numbers of young pods removed at this stage were considerably greater in the 100% than in the 50% pod removal treatment (Table 39). Of course, in the latter only half the number of pods were removed, but if the number of removed pods in this treatment is doubled, to give an approximate estimate of the numbers of young pods on these plants, it can be seen that there were more than twice as many young pods on the plants from which all the pods had been removed 8-9 days before than after 50% pod removal. This compensatory setting of pods from later formed flowers in response to flower or young pod removal has been studied in some detail in previous years (e.g. PPR 1975-76, Chapter II-2).

In cvs ICP-1 and APAU-2208, the plants were able to compensate completely for the removal of 50% of the young pods: indeed in cv. ICP-1 after this treatment yield and pod number per unit area actually increased (Table 40 and Fig.9). By contrast cv. HY-3A was unable to compensate fully, and yield and pod number were about 30% lower than in the control.

After 100% pod removal, yield declined by 63% in cv. HY-3A, and by 40% in cv. ICP-1. However, cv. APAU-2208 was able to compensate fully for the loss of pods (Table 40 and Fig.9).

Table 38. Dates of 50% flowering and treatment imposition in different cultivars.

Cultivar	Date of 50% flowering	Treatment	Date of treatment imposition	
			First time	Second time
ICP-1	25-10-1982	T2	11-11-82	17-11-82
		T3	9-11-82	18-11-82
		T4	8-11-82	16-11-82
		T5	10-11-82	17-11-82
HY-3A	31-10-1982	T2	11-11-82	18-11-82
		T3	10-11-82	19-11-82
		T4	9-11-82	19-11-82
		T5	12-11-82	18-11-82
APAU-2208	28-10-1982	T2	11-11-82	17-11-82
		T3	10-11-82	18-11-82
		T4	9-11-82	18-11-82
		T5	12-11-82	17-11-82

Pod damage

The two techniques for damaging the pods that we used were intended to simulate damage by insects such as pod borers. Clipping off the distal plant of young pods is a simple way of reducing the seed number, and this is the method we have used in previous years. The pod stapling technique is an innovation this year. It has the advantage of simulating pod borer damage more closely, by puncturing two of the locules in each pod and causing seed abortion. However, it is slightly more time-consuming than the clipping treatment.

Both methods led to reduction in seed number per pod in the treated pods of around 50% (Table 41) and were therefore approximately equally effective in reducing the reproductive sink size.

When pods were damaged by either method, the trauma seems to have caused a considerable proportion to be shed from the plants. This is indicated by the fact that at the time of harvest in most cases less than half the total number of pods were treated once (Table 41). Of course, one reason for this could be that the treatments were not carried out thoroughly and that many pods were missed, but in fact this work was done carefully and it is unlikely that more than a small percentage escaped treatment. Most of the untreated pods were probably set after the treatments were imposed, perhaps partly in compensation for the shedding of damaged pods, and partly in compensation for the damage to the remaining treated pods.

In cv. ICP-1, both pod clipping and stapling led to yield reduction of about 20% (Table 40 and Fig.8). The yield reductions were not so severe as in previous experiments with this cultivar where clipping off half of each pod led to yield reductions of about 50% (PPR 1977-78,Table 23; PPR 1978-79, Table 19), but in these experiments the pod clipping was done continually throughout the reproductive period, 8 or 9 times, whereas in the present experiment it was done only twice. This allowed for more compensation through the subsequent setting of pods which were not clipped (Table 41). A similar degree of compensation with this cultivar was observed in an experiment in the rabi season where pod clipping was done only twice (PPR 1980-81, Table 36) (Fig.10).

In cv. HY-3A, pod clipping led to a yield reduction of 60% (Table 40). This severity of this effect seem to have been due to the shedding of many of the damaged pods (Table 41), and to the very limited ability of this cultivar to compensate for pod loss (Table 41, Fig. 8). In previous years clipping off half of each pod in this cultivar also led to yield reductions of 55-65% (PPR 1978-79, Table 19; PPR 1980-81, Table 36)(Fig.10).

By contrast, damaging the pods by stapling them resulted in less pod shedding in this cultivar (Table 41) and led to a yield reduction of only 20% (Table 40).

Cv. APAU-2208 showed no yield reduction at all after either type of pod damage; indeed the yields were somewhat higher than in the control (Table 40, Fig 8). As in the case of ICP-1, pod stapling resulted in more abscission of treated pods than pod clipping (Table 41), but compensation for pod loss and pod damage took place through the setting of extra pods: there were 33% more pods after pod clipping and 36% more after pod stapling than in the controls (Table 40).

Table 39. Number of pods removed per square meter in the 50% and 100% pod removal treatments.

		Pod number/m^2		
		Cultivar		
Percentage removed	Time of removal	ICP-1	HY-3A	APAU-2208
50%	First	85	16	43
	Second	62	27	37
	Total	147	43	80
100%	First	87	62	80
	Second	296	123	195
	Total	383	186	275

SE for comparison of times of removal within a cultivar 11.9

SE for comparison of cultivars within times of removal 22.9

Table 40. Effects of pod removal (PR) and clipping and stapling the pods on yield and yield components of 3 pigeonpea cultivars.

	Control	50% PR	100% PR	Clipping	Stapling	SE for comparison within cultivars
Yield (gm/m^2)						
ICP-1	52.7	71.0	31.2	42.2	43.3	
HY-3A	51.8	37.0	19.1	20.0	41.4	9.3
APAU-2208	49.1	53.2	55.5	54.9	63.5	
Pod number/m^2						
ICP-1	233	285	135	248	211	
HY-3A	134	98	51	67	114	30
APAU-2208	230	202	260	307	313	
Seeds per pod						
ICP-1	2.58	2.80	2.58	1.94	2.16	
HY-3A	2.80	2.75	2.68	2.29	2.37	0.09
APAU-2208	2.65	2.85	2.59	2.20	2.44	
100-seed weight(g)						
ICP-1	8.78	8.89	8.99	8.76	9.50	
HY-3A	13.20	14.22	13.81	12.53	14.53	0.82
APAU-2208	7.95	8.90	8.18	7.97	8.27	

Table 41. Effect of pod clipping and pod stapling on treated and untreated pods harvested from treated plants.

Variable	Harvested pods	Cultivar ICP-1	Cultivar HY-3A	Cultivar APAU-2208	Mean	SE±
POD CLIPPING TREATMENT						
Pod No/m^2	Untreated	115	51	189	118	19.2
	Treated	133	16	117	89	23.5
Seed No./pod	Untreated	2.56	2.60	2.76	2.64	0.11
	Treated	1.39	1.31	1.30	1.33	0.04
100 seed wt. (gm)	Untreated	8.98	12.62	8.21	9.94	0.36
	Treated	8.40	11.85	7.07	9.11	0.22
Seed yield/m^2 (gm)	Untreated	26.7	17.5	43.9	29.4	6.05
	Treated	15.5	2.5	11.0	9.7	2.67
POD STAPLING TREATMENT						
Pod No/m^2	Untreated	147	55	228	143	27.9
	Treated	65	59	85	70	20.7
Seed No/pod	Untreated	2.56	2.95	2.86	2.79	0.19
	Treated	1.27	1.52	1.38	1.39	0.16
100-seed wt (gm)	Untreated	9.24	15.08	8.35	10.89	0.14
	Treated	11.55	13.07	7.98	10.87	1.67
Seed yield/m^2 (gm)	Untreated	34.8	25.7	54.2	38.2	8.11
	Treated	8.5	15.6	9.3	11.2	7.27

Compensation in all cultivars, to the extent that it occurred, was indeed almost entirely due to the setting of more pods. In the pod damage treatment there was no increase in the weight of the remaining seeds in the remaining locules of the treated pods, with the exception of cv. ICP-1 after pod stapling (Table 41). But even in this case, the proportion of the total yield due to the increased weight of these seeds was only 4%.

General discussion

These results reveal marked cultivaral differences in the ability to compensate for the loss of pods and for pod damage. As in previous years, cv HY-3A was inferior in compensatory ability to cv. ICP-1; and cv APAU-2208, identified by the Pulse Entomologists as showing an exceptional ability to compensate after heavy pest attack, was able to compensate completely after all the treatments were imposed (Fig. 8). This finding is encouraging. It confirms the field observations of the entomologists on the one hand, and on the other hand shows that artificially imposed damage to the plants in experiments of this type can indeed give information relevant to understanding the plants' response to pest attack.

This experiment is at present being repeated with the same cultivars; it will be important to see if the present results can be confirmed, because in this experiment the yield levels were unusually low (only around 500 kg/ha) and the relative advantage of cv. APAU-2208 might be less pronounced under more favourable environmental conditions.

Undoubtedly, the ability to compensate for pod loss or damage by producing additional pods is a valuable and important character, and will not be revealed in yield tests carried out with effective pesticide sprays. Something of its importance is revealed in the present experiment by comparing the yields in different treatments. In the controls, cv APAU-2208 yielded 6% less than cv. ICP-1 and 5% less than cv. Hy-3A (Table 40). But after 100% pod removal, it yielded 78% more than cv.ICP-1 and 190% more than cv. HY-3A. After damage to the pods by stapling, it outyielded cv. ICP-1 by 46% and HY-3A by 53%. These findings support the findings of the Pulse Entomologists that yield tests carried out under unsprayed conditions with a heavy incidence of Heliothis and other pests give results very unlike those of breeders' trials, and which are probably much more relevant to the condition in most farmers' fields.

The entomologists' method of identifying cultivars with a good ability to compensate for pod loss or damage by observing their performance under heavy pest attack is simple and direct. An alternative method, which could be used to confirm entomologists' findings or even to screen cultivars or breeding material would be to remove all the developing pods from the plants. In previous experiments, we have removed pods repeatedly, at least twice, but for screening purposes this would be too tedious. It might be possible to obtain reliable results with a single pod removal treatment. However, the ability to compensate probably depends on environmental factors such as water availability. In one year even cv. HY-3A was able to compensate completely after pod [illegible]oval for up to 5 weeks (PPR 1976-77, Fig.11). This result was obtained with plants grown on Vertisol, with unusually heavy rain during the reproductive phase in November. However, in other years flower and pod removal for 3-4 weeks have resulted in yield reductions in medium duration cultivars (PPR 1975-76, Tabl[illegible], PPR 1977-78, Table 23-25) as they did this year in cvs ICP-1 and HY-3A. [illegible] screening purposes, it might be possible to obtain differential responses of cultivars grown on Alfisols or similar light soils with a single depodding treatment say 3 or 4 weeks after 50% flowering.

It would not be feasible to carry out pod stapling or pod clipping treatments on a large scale, since they are very time-consuming. However, this year's results show that the ability to compensate for pod damage may be indicated by the ability to compensate for pod loss: cv. APAU-2208 compensated completely for both; and cv. HY-3A was least able to compensate for either.

The physiological basis of the remarkable compensatory ability of cv. APAU-2208 is unknown, and this cultivar has no obvious characteristics which distinguish it from many other indeterminate medium duration cultivars, except for the fact that it has purple pod walls; but it seems unlikely that this is a relevant factor. Its physiological advantage may have something to do with the hormonal factors affecting pod set, and/or it may have some general physiological advantage such as a better water status during the reproductive phase, perhaps as a result of a more effective root system. It may be significant in this connection that it produced more total dry matter than the other cultivars - a mean of 530 g per sq.m. compared with 447 in cv. ICP-1 and 509 in cv. HY-3A (SE 18).

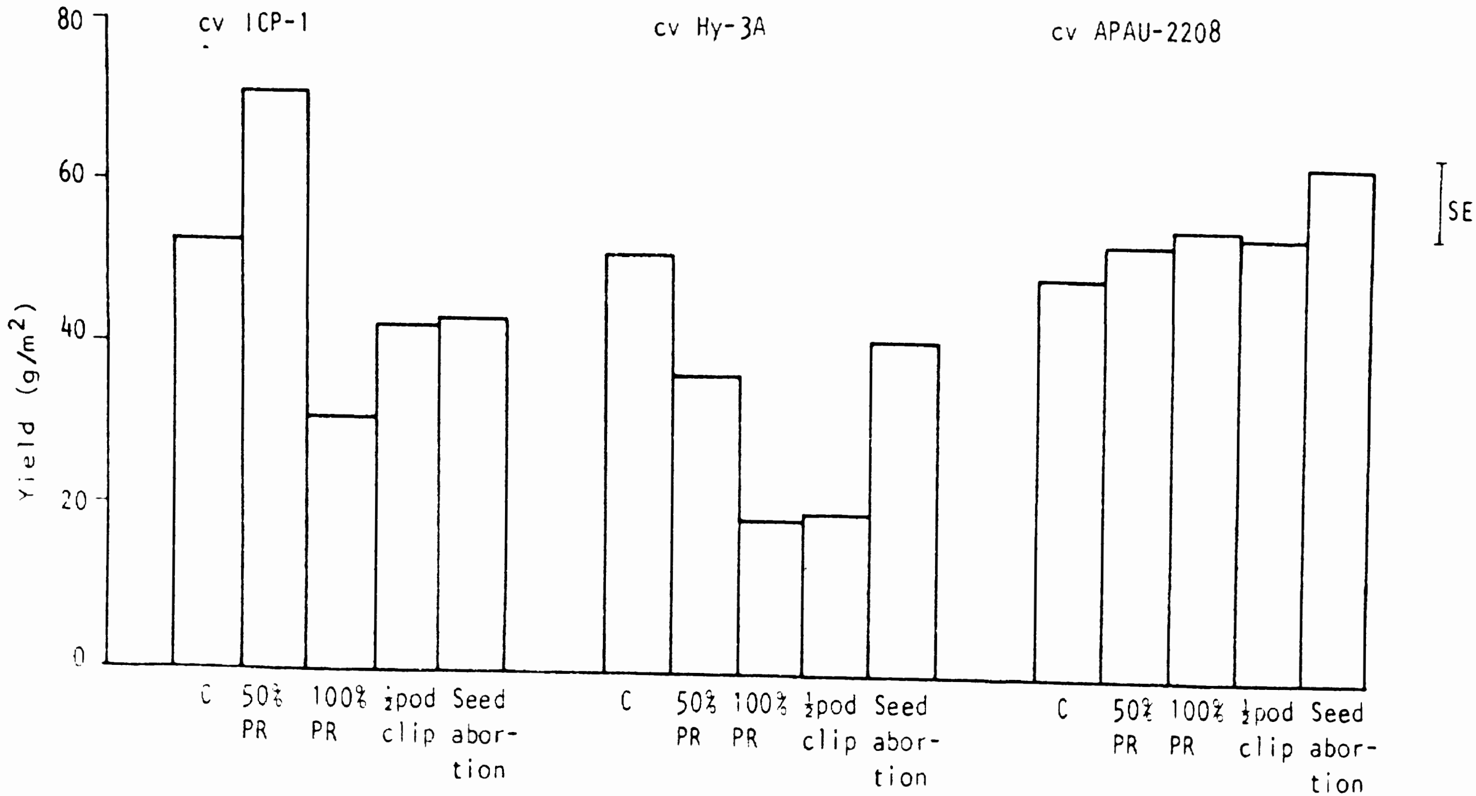


Figure 8. Yield of 3 pigeonpea cultivars after different kinds of pod damage.

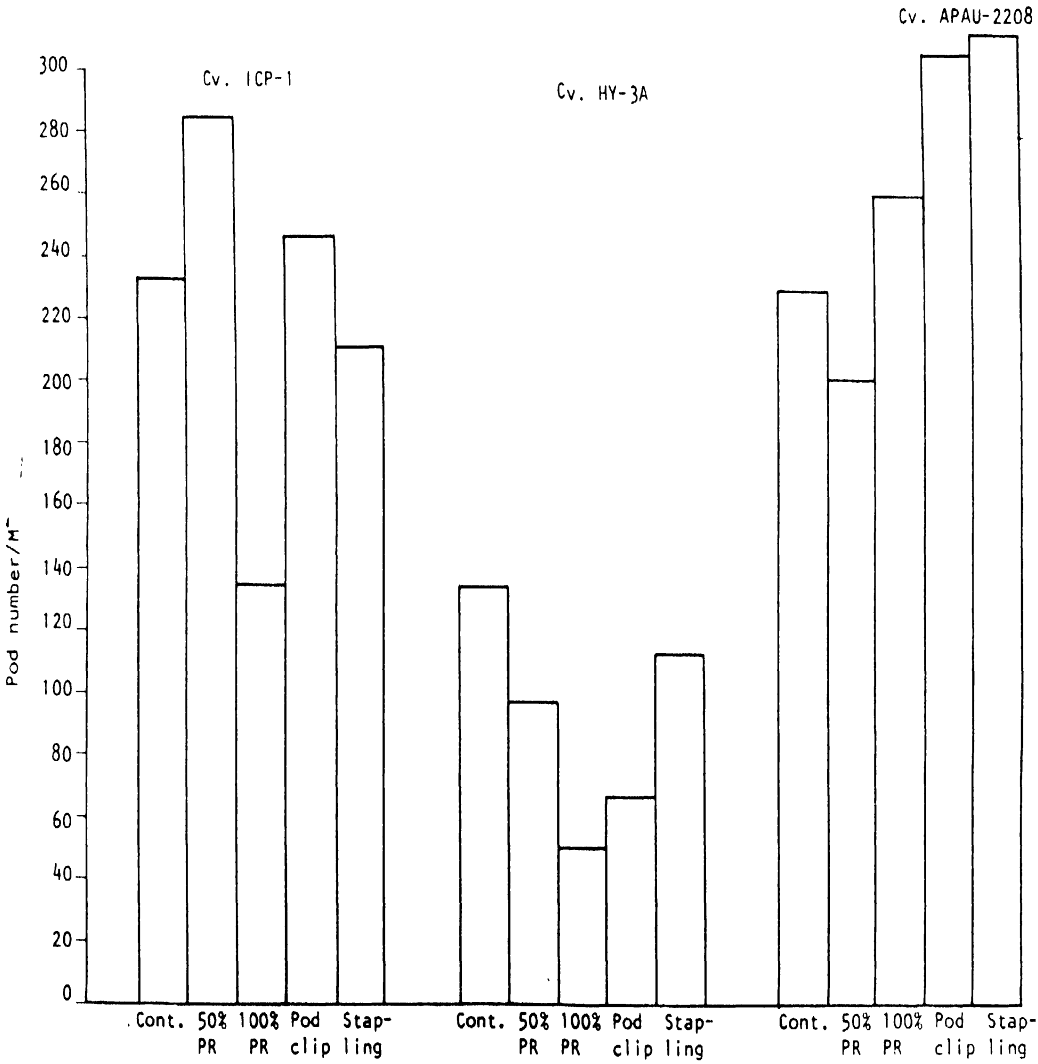


Figure 9. Pod number per square metre of 3 pigeonpea cultivars after different kinds of pod damage.

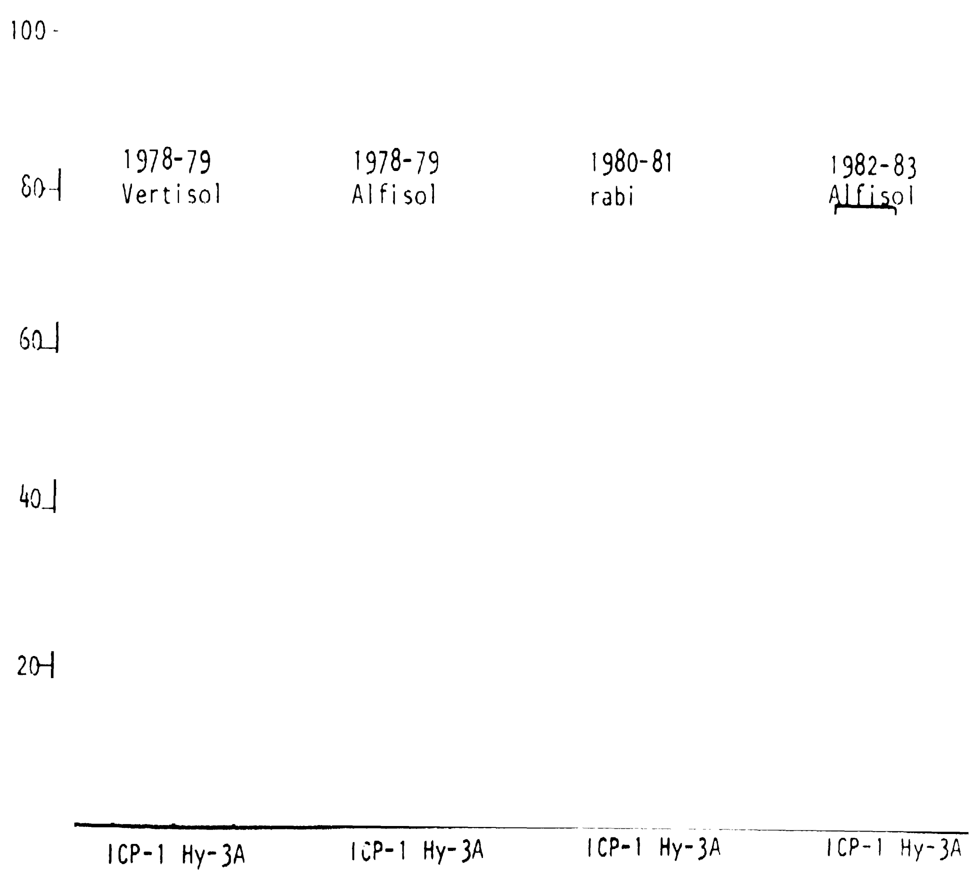


Figure 10 Yield reductions relative to control as a result of 50% pod clipping in cvs. ICP-1 and Hy-3A.

IX. Effects of clipping of apical bud on growth and yield:

Our earlier studies on the effects of clipping off the shoot apex have shown that when this is done around the time of flowering, it does not result in increased yield (PPR 1975-76, Chapter II.3). However recent reports indicate that early clipping can lead to increased yields of both soybean and pigeonpea (Tayo, T.O. Agric.Sci.Camb (1980) 95, 409-416; and Tayo, T.O. J. Agric.Sci. Camb, (1982) 98, 79-84). To test this, we conducted an experiment in which clippings were carried out at different stages of growth.

Materials and Methods

Cultivar C-11 was sown on 75 cm ridges at 75 x 20 cm spacing on a Vertisol field BP-6 on 24-6-82. Five apex clipping treatments were imposed in RBD in three replications. Plot size was 3 x 4m.

The five clipping treatments and their dates of imposition were as follows:

T1	Clipping 3 weeks after sowing (15-7-82)
T2	Clipping 6 weeks after sowing (7-8-82)
T3	Clipping 9 weeks after sowing (27-8-82)
T4	Clipping 12 weeks after sowing (17-9-82)
T5	Control

Clipping was done by removing the apex of all main stems and branches using a sharp blade. Fifty percent flowering occurred on 25-10-82 and maturity on 20-12-82. At maturity observations on yield, yield components and total dry matter were recorded.

Results and discussion

A significant increase (P=0.05) in yield of 10% was observed after the apex clipping treatment at 3 weeks, whereas the other treatments were not significantly different from the control (Table 42). The dry matter production was also slightly greater in the 3 week apex clipping treatment. The greater biomass production in this treatment was associated with greater number of secondary and tertiary branches per plant. It is to be noted that there were no primary branches present in 3 week old plant at the time apex clipping was carried out, and their number at maturity was similar to the controls. However, early initiation of primary branches as a result of loss in apical dominance might have led to earlier development and increased numbers of higher order branches.

The results of this study indicate that damage caused mechanically or by pests such as leaf webber in the early stages of growth may not be detrimental to pigeonpea growth and infact it could lead to a small increase in yield. However, apex clipping as a farming practice to increase yield may not be of much economical use.

Table 42. Effect of apex clipping on yield, components of yield and total dry matter.

Plant character	Apex clipping 3 weeks	6 weeks	9 weeks	12 weeks	Control	Mean	SE
Yield/ha(kgs)	2032	1906	1810	1867	1833	1890	43.5
Yield/plant (gms)	35.11	33.09	30.76	30.76	31.90	32.33	1.16
Total dry matter/ ha(kgs)	8148	7963	7241	8111	7815	7856	247.7
Total dry matter/ plant(gms)	140.4	138.5	122.6	133.6	136.0	134.2	5.16
Harvest index	0.25	0.24	0.25	0.23	0.23	0.24	0.01
100 Seed weight(g)	9.76	9.92	9.81	9.97	9.54	9.80	0.38
Seed No./Pod	2.90	2.97	2.74	2.88	2.96	2.89	0.12
Pod No./plant	124	112	114	108	114	114	4.03
Primary branch No./plant	21.23	23.07	22.43	21.07	21.87	21.93	1.33
Secondary branch No./plant	51.20	38.50	42.00	45.20	41.20	43.60	6.49
Tertiary branch No./plant	27.10	18.40	25.90	27.50	20.20	23.80	4.32
Total plant No./m2	5.81	5.78	5.93	6.11	5.74	5.87	0.19

X. Screening for tolerance to soil salinity

We continued screening advanced breeding lines for salt tolerance. Last year we screened 79 advanced breeding lines in a saline alkaline field (PPR 1981-82 Chapter VI). Twenty seven lines were found better than the tolerant check (cv. C-11). These lines were again screened for salt tolerance this year both in the field and also using the pot screening technique described last year (PPR 1981-82, p.49).

Materials and methods

Field screening: Field screening was carried out in saline alkaline field BS-8C according to method described previously (PPR 1980-81, Section IV). Part of the field in which the lines were planted had a gradient of salinity along which rows were to be planted (Table 43).

Sowing was done on 9.7.82. A row of tolerant check cv. C-11 and a row of susceptible check cv. HY-3C were sown either side of each test row. The test lines were those listed in PPR 1981-82, Table 27. Both row to row and plant to plant spacing was 30 cm. Length of each row was 27 m which was not replicated.

Visual scoring was done on 1-9 scale (1 resistant, 9 susceptible) of test lines and checks was done once during the vegetative phase 6.10.82 and in the reproductive phase on 9.12.1982.

Pot screening: The same advanced breeding lines (except ICPL-238) used in the field screening were included in pot screening. The method described last year (PPR 1981-82, Chapter VI)was modified slightly. Instead of using mixture of pure salts to create salinity, the salts on the surface of a naturally saline alkaline soil were collected from field BS-8C and mixed with normal soil to create two levels of salinity, which were 3.0 and 4.8 mmhos/cm. Planting was done on 9.9.82. Five seeds per pot were planted with 3 replicate pots in each treatment. Until emergence pots were irrigated from the top but once emergence occurred, pots were irrigated to field capacity from top and bottom of the pots alternatively as and when necessary.

First visual scoring was done on 4.10.82 and second on 14.10.82 on 1-5 scale, 1 being resistant 5 being susceptible.

Results and discussion

The field used for salt tolerance screening was the same one used last year. The lines tested this year were those found tolerant.

This year in the field screening only the 8 lines listed in Table 44 were found to be more tolerant than the tolerant check, cv. C-11. There was a higher level of salinity in the area used this year than last year, and thus the screening conditions were more severe.

In the pots, visual scorings of the plants at two levels of salinity were taken into account to produce the list given in Table 44 of cultivars which were more tolerant than cv. C-11, or of a similar level of tolerance. There was a fairly good agreement with the field scorings. Of the 7 cultivars found tolerant in the field which were tested in pots, 4 were found tolerant in pots, and one was moderately tolerant. Only two cultivars found tolerant in the field were not particularly tolerant in pots, and only two found tolerant in pots were not particularly tolerant in the field.

From these tests we can conclude that in addition to the tolerant check, cv. C-11, cvs. ICP-1-6, ICPL-239, ICPL-308 and ICPL-309 are relatively tolerant to soil salinity of the type encountered in the alkaline-saline field in which they were tested, and from which salts were taken for use in the pot screening trial. Whether they are also tolerant to other kinds of soil salinity remains to be seen.

Table 43. Salinity level (EC mmhos/cm) at different depth in saline field BS-8C

Soil depth (cm)	EC mmhos/cm		
	Spot 1	Spot 2	Spot 3
0-15	2.7	2.8	0.4
15-30	3.05	2.9	0.72
30-45	3.5	3.2	2.4
45-60	3.8	3.1	2.7
60-75	3.4	2.8	1.9
75-90	5.5	1.3	2.1
Mean EC of profile	3.6	2.6	1.7

Table 44. List of lines tolerant to salinity identified by screening in the field and in pots.

Field	Pots
ICP-1-6	ICP-1-6
ICPL-97	
ICPL-238	(not screened)
ICPL-239	ICPL-239
ICPL-248	(moderate tolerance)
ICPL-264	
ICPL-308	ICPL-308
ICPL-309	ICPL-309
	ICPL-304
	ICPL-230

XI. Screening for waterlogging tolerance

We continued screening advanced breeding lines and some phytophthora blight resistant lines for waterlogging tolerance in pots. In pots the Phytophthora build up can be avoided by using Phytophthora inoculum free soil.

Materials and Methods

Sixty seven lines to be tested were supplied by pigeonpea breeders and Genetic Resources Unit (lines with ICP No) of ICRISAT. These were planted in round plastic pots (7" diameter) on 7-4-83. The pots were perforated and lined with muslin cloth at bottom and filled with black soil. Five seedlings were raised in each pot and there were three replications for each line. The plants were allowed to grow under adequate water supply outdoors until 23-5-83, when they were submerged in waterfilled plastic troughs for five days, where the number of plants which had died was recorded. The pots were removed from the water on 28-5-83 and the excess water in the pots drained out through the perforations at within a few hours. The number of dead plants was again recorded on 31-5-83. Cultivars showing more than 25% mortality were regarded susceptible.

Results and Discussion

The pot culture method provide an opportunity to screen in conditions where disease like *Phytophthora* etc., can be avoided by using soil free of Phytophthora inoculum. However, sterilized soil may not give consistent results as using this we did not obtain satisfacotry differential response to water logging. Whereas when unsterilized soil was used, a clear cut differential response was obtained. Sixteen lines out of 67 which shoed less than 25% mortality are listed in Table 45. Further work on factors responsible for variation in water logging response is in progress.

Table 45. Some promising lines for water logging tolerance

1. BDN-1**
2. ICP-2376
3. ICP-2505
4. ICP-2974*
5. ICPL-247
6. ICPL-264
7. ICPL-290
8. ICP-7210
9. ICP-7910
10. ICP-7151*
11. ICP-5860*
12. ICPL-308
13. ICPL-304
14. ICPL-239
15. ICPL-232
16. ICPL-231

** Tolerant check

* Tolerant during 1980-81 screening also

XII. Effects of soil cracking on yield

(with N.P. Saxena)

Vertisols have the characteristics feature of cracking as they dry out. Experiments conducted with chickpeas (CPR 1978-80, Chapter XII) and pigeonpeas (PPR 1980-81, Chapters III and VII; PPR 1981-82, Chapter X) provided circumstantial evidence that cracking may be harmful for both crops and could lead to yield reductions, probably through its damaging effects on the root system.

This year we investigated the influence of soil cracking in different land management systems both in the normal and the post-rainy seasons. We also studied the east- west asymmetry of the root system of pigeonpea developing in the rainy season, and investigated the effects of cutting the roots of pigeonpeas.

Unfortunately the main experiment carried out in the normal season was severely affected by the wilt disease, and data could be obtained from only a few relatively unaffected plots.

Materials and methods

1.Cracking trial in the normal season

The trial was planted in Vertisol field BP-5 on 23-6-82. There were seven treatments in an RBD with 4 replications, involving flat plantings, with compaction zones 50,100 and 150 cm apart produced by driving a tractor through the plot, and plantings on 150 cm broad beds. The broad beds were oriented north south. The cultivar was C-11, which is susceptible to the wilt disease. It reached 50% flowering on 25-10-82 (124 days after sowing) and matured on 23-12-82.

The plants in most plots were severely affected by the wilt disease. Only in the case of treatments 5-7 were there a sufficient number of surviving replicates to enable any reliable comparisons to be made. These treatments involved planting 3 rows 30 cm apart with a plant-to-plant spacing of 20 cm within each row on broad beds. Since the broad beds and furrows were 150 cm apart, this meant that the outer row on one broad bed had a 90 cm gap between it and the nearest row on the next broad bed. In treatment 5, the three rows were placed in the centre of the broad bed; in treatment 6 all were displaced 15 cm towards the east side of the broad bed, and in treatment 7, displaced 15 cm towards the west. The plot sizes were 9 x 7.5 m, of which 4 m long rows were harvested (on 23-3-83) separately.

The data were too limited with too few surviving replications for any reliable comparisons to be made of the effects of displacing the rows towards the east or west of the broad beds, so the data were pooled from all these treatments, from 7 sections (4m long) of broad bed altogether, and the effects of row position (east, central and west) compared. Standard errors were calculated by analysing the data for the row positions as if they were randomized treatments within a RCB design with 7 replications.

2. Observations on yields of plants on the east and west sides of ridges the normal season

In the trial on response of 10 different cultivars to row spacing, described in Chapter 4, the rows were harvested separately. Since the trial was planted on 75 cm ridges and furrows running north-south, in the 37.5 cm row spacings, there was a row on the east and west side of each ridge. The yields in these rows were compared.

3. Studies on the asymmetry of the root system of pigeonpeas grown in rainy season

In order to study the effect of westerly monsoon winds on the development of the root system, cv. C-11 was planted on 30-6-82 in 30 x 30 x 30 cm plastic pots containing Alfisol, with a row of 3 plants along the centre of each of 6 replicate pots. The pots were kept in an exposed place near the screenhouses with the rows oriented north-south. On 2-11-82 the soil on the east and the west side of each pot was removed and the roots washed out of it. These were separated into large roots (main laterals and the tap root) and small fibrous roots, and the dry weights were recorded.

4. Cutting of roots on the east and west sides of pigeonpea rows

In the trial on the effects of irrigation described in Chapter 3, a small experiment was carried out to investigate the effects of cutting the roots of cv. ICP-1-6 during the reproductive phase. Four rows within each replicate plot were marked, and randomly assigned to the following treatments:

1 and 2: Controls (no treatment)

3: Roots cut by inserting a sharp spade to a depth of 20 cm in a 2 m long line 10 cm from the row of plants, on the east side of the row.

4: As above, but cut on the west side of the row.

The treatments were carried out on 10-11-82, 10 days after 50% flowering.

There were 4 replicate plots in both irrigated and unirrigated treatments. The 2m rows treated as above were harvested separately and the yield and yield components recorded.

5. Cracking trial in the post-rainy season with pigeonpeas and chickpeas

The experiment was conducted in Vertisol field BP-11C. The seed bed was prepared in four different manners; flat; flat but compacted at 150 cm intervals by tractor wheels; 60 cm ridges and furrows; and 150 cm broad bed and furrows. Sowing was done on 2-11-83 in rows 30 cm apart with a plant to plant spacing of 10 cm. After every four rows, sowing of one row was skipped leaving a 60 cm gap which was a furrow in the broad bed and furrow system, and a compacted zone in the flat compacted treatment. In other treatments, to maintain uniform planting pattern, one row was skipped. Plot size was 7.5 x 4 m, and there were 3 replications. Both pigeonpeas (cv C-11) and chickpeas (cv. Annigeri) were planted in this trial, randomized within the land preparation treatments, which formed the main plots of a split-plot design and chickpeas and pigeonpeas the subplots.

The pigeonpeas reached 50% flowering on 14-1-83 and matured on 8-3-83. The chickpeas reached 50% flowering on 17-12-82 and matured on 26-1-83. At maturity individual rows were harvested (3.5 m long).

Analysis of variance of yield was done in two different manners. In one case the border effect was studied in different land management systems by subtracting yield of the 2 central rows from 2 border rows; the resultant differences were analyzed as RBD. In the other case the 2 central and 2 border rows were directly compared in the different treatments.

Results and Discussion

1. Cracking trial in the normal season

The only data which could be salvaged in sufficient quantity from this trial, from plots which more or less escaped the wilt disease, concerned plantings with 3 rows 30 cm apart on 150 cm broad beds and furrows. The central row received competition from the two outer rows on each broad bed, but each outer row had a 90 cm gap between it and the nearest outer row on the next broad bed. The growth and yield of the outer rows would therefore be expected to be greater than that of the central rows because they were subjected to less competition. (This type of planting differs from that investigated last year and described in PPR 1981-82, Chapter X, where the rows were planted an equal distance apart, at 50 cm, and where there was therefore no such border effect). The outer rows did indeed grow and yield more than the central rows (Fig 11). Interestingly, there was a distinct difference between the east and west outer rows, with the east ones yielding 32% more. A similar difference was found last year, with eastern rows yielding 24% more than western rows in the first harvest, and 28% more in the second harvest (PPR 1981-82, Tables 30 and 31).

The east-west row difference in total dry matter was much smaller (Fig.11) with only 6% more in east than west rows. This suggests that the relative advantage of the east over the west rows developed during the reproductive phase and that in the vegetative phase the difference may not have been so apparent. This is confirmed by the data for the total dry weight of the plants sampled for growth analysis on 18-10-82, one week before flowering. In the same treatments, (T5 to T7), the mean dry weights in the east, central and west rows were 420, 293 and 436 g/m row respectively. In other words, the plants in the east and the west rows weighed almost the same, with 4% more in the west than east rows. This difference was not statistically significant.

The lower yield in the west rows in spite of the similar growth of the plants in the east and west rows supports the interpretation given to results of this type last year that the yield in the west rows was reduced relative to the east rows as a result of more root damage during the reproductive phase due to soil cracking in the furrows. This cracking occurred as the soil dried out after the end

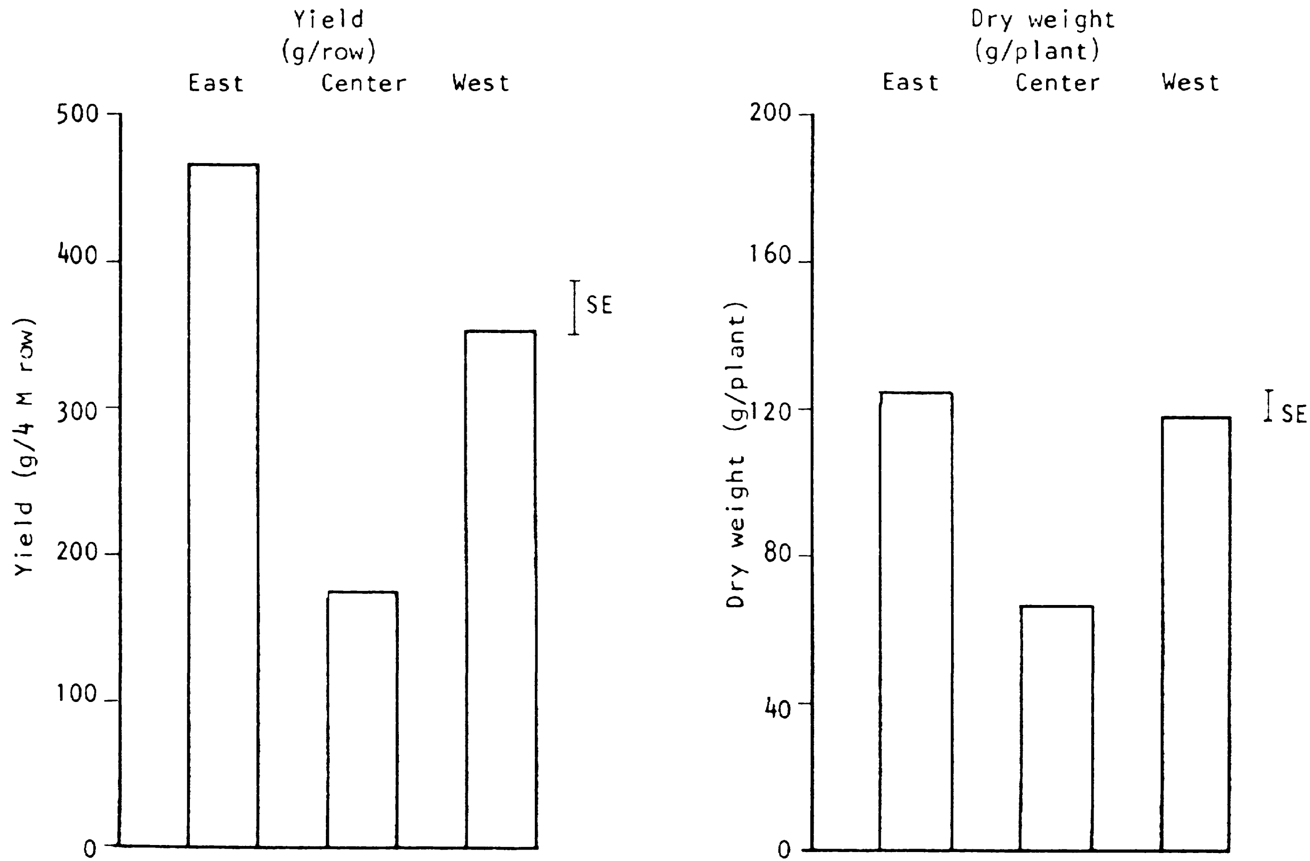


Figure 11. Effect of row position on broad beds on the growth and yield of cv. C-11 grown in the normal season at ICRISAT Center. The mean yield in these plots was 1660 kg/ha.

of the monsoon. Rows on the west of the broad beds would be more affected than on the east sides because of the asymmetrical development of the root system, with more lateral roots on the west side, as a result of the westerly winds during the monsoon season (PPR 1980-81, Chapter X).

2.The yields of pigeonpeas grown on the east and west sides of ridges the normal season

We found in 1980-81 that pigeonpeas grown on Vertisol with two rows on either side of 75 cm ridges oriented north-south showed a remarkable pattern of yield, with more in alternate rows, i.e. those on the east or west sides of the ridges (PPR 1980-81, Fig.7). Unfortunately we did not have a record as to which rows were yielding more, east or west.

This year we recorded yields row-wise in the spacing trial described in Chapter 4. In two of the spacings, 37.5 x 6, and 37.5 x 20 cm, the rows were grown on the east and west sides of 75 cm ridges. The means for 10 cultivars for the two spacings are shown in Fig. 12. It can be seen that there was a consistent tendency for rows on the west sides of the ridges to yield more than on the east sides.

This pattern was not as clear as that observed in 1980-81, when it showed up in almost every pair of rows. Nevertheless, the tendency was apparent in most pairs of rows. Some representative data for individual rows are shown in Fig. 13, for cv. C-11.

It is puzzling that in this experiment rows on the west side should have yielded more, whereas in the broad beds, rows on the east side yielded more. It is easier to interpret the latter results in terms of the effects of soil cracking on an asymmetric root system; the same results would have been expected on ridges and furrows. We have no plausible explanation at present for this discrepancy.

3.The asymmetry of the root system of pigeonpeas grown in the rainy season

During the monsoon, the strong prevailing westerly winds cause the young plants to bend over towards the east. This leads to a predominance of branching on the westerly side of the plants (PPR 1974-75, pp 72-73). Observations in the field of exposed lateral roots show that more tend to be located on the westerly side of the plants, perhaps in response to the greater mechanical tension exerted on the roots on that side of the plant as a result of the action of the wind.

We attempted to quantify this effect on root asymmetry by washing out the roots of plants grown in north-south rows in plastic pots, from which the root system could be recovered by washing the soil. The results indicated that there were indeed more woody lateral roots on the west of the rows than in the east, an average of 4.2 g/pot as opposed to 3.3 (SE 0.14), or in other words an average of 33% more on the westerly side. An excess of west over east was apparent in each of the 6 replicate pots, and the difference was statistically significant at the 5% level.

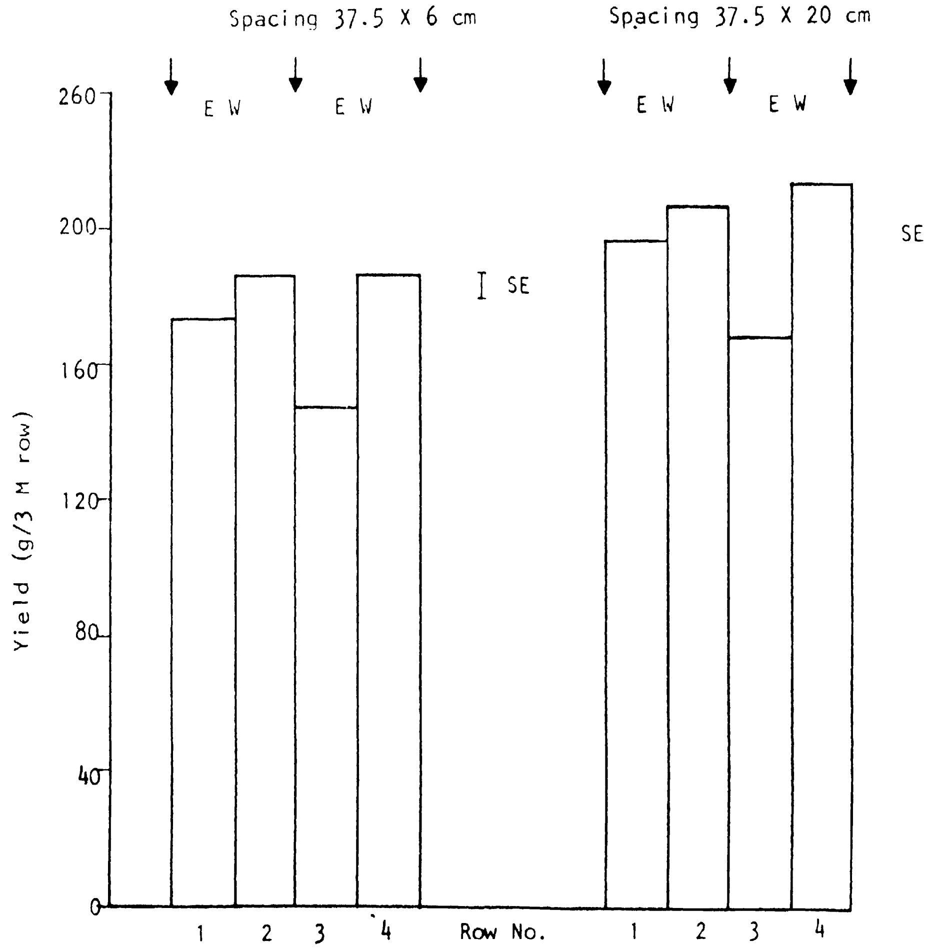


Figure 12. Yields of rows grown on east (E) and west (W) sides of 75 cm ridges on Vertisol (Means for 10 cultivars). Positions of furrows are indicated by arrows.

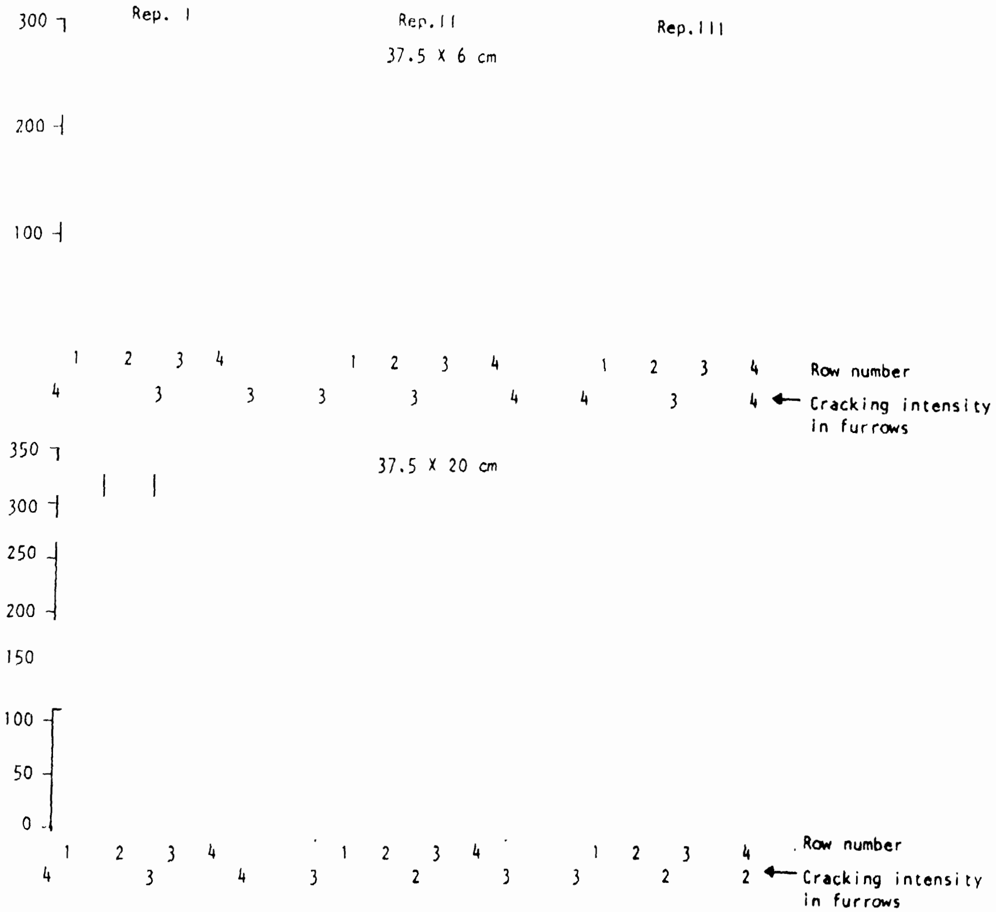


Figure 13. Yields of individual rows of cv. C-11 on the east (E) and west (W) sides of 75 cm ridges on Vertisol, in three replicate plots and at two spacings. Cracking intensities in the furrows were scored on a 0-5 scale, with large and deep cracks being rated at 5, no cracks being rated at 0.

This result supports our interpretation of the differential effects of soil cracking on the rows on the west and east sides of broad beds in terms of an asymmetric root system.

In the field, the asymmetry of the main lateral roots would be expected to result in an asymmetry of the smaller roots growing from them. In pots this would not necessarily be the case, since in a confined soil volume young roots grow round the pot to exploit the soil on all sides, especially if the plants are grown for months in relatively small pots, as in the present experiment. And in fact the weight of small fibrous roots on the west and east sides was similar, 8.8 and 8.6 g/pot respectively.

4.Effects of cutting the roots on the east and west sides of pigeonpea rows

This experiment was carried out to test the hypothesis that cracking on the east and west sides of a pigeonpea row would have different effects owing to the larger number of lateral roots on the west side. An attempt was made to simulate the root cutting effect of cracking by cutting the roots with a spade to a depth of 20 cm.

However, the root cutting treatments had no significant effects on yield (Table 46) on yield components, either in the irrigated or unirrigated plants.

Last year a yield reducing effect of root cutting was observed in an experiment carried out by Mr. K.L. Srivastava (PPR 1981-82, p.65), and it is surprising that there was no detectable effect of the treatments we imposed this year. Perhaps the depth to which the roots were cut was not sufficient to cause enough damage to harm the plants; the remaining part of the root system must have been able to adjust to maintain a more or less normal supply of water and nutrients to the shoots. The damage caused by cracking is likely to be more severe than that caused by our treatments, since the cracks extend much deeper into the profile.

5.Cracking trial in the post-rainy season

With pigeonpeas sown in the rainy season, cracks developing in the post rainy season, would be expected to rupture the already established root system with consequent harmful effects to the plant.

By contrast, with crops sown after the end of the rainy season, cracks develop while the plants are still young and before an extensive root system has had time to develop. Consequently less damage would be expected. In fact observations in 1982-83 on chickpeas sown early (in September) and at the normal time (in October) showed that the former had more root damage by cracking than the latter. This could be seen simply by looking into the cracks; with the September sown plants many stretched and ruptured roots were visible in the cracks, but only a few with the October sown plants. If cracking develops before the roots grow into the cracking zone, presumably they grow around the cracks.

Table 46. Effect of cutting the roots on the east and west side of rows of cv. ICP-1-6 grown on Vertisol in the normal season with and without irrigation.

Treatment	Yield (g/2m row) Non-irrigated	Irrigated	Mean
Control	352	417	385
Control	312	369	340
Cut on east	350	362	356
Cut on west	323	402	363
Mean	335	388	

SE	
Irrigation	22
Treatments	31
Irrigation x treatments	43

CV: 17%

In this trial the four types of land preparation (control (flat seedbed), flat seed-bed with compaction zones every 150 cm, 60 cm ridges and furrows, and 150 cm broad beds and furrows) gave different patterns of soil cracking. However, there was no significant effect on overall yields of either chickpea or pigeonpea (Table 47).

However, an interesting difference between the treatments emerged when the yields of the border and central rows of each 4-row strip were compared. The border rows yielded more than the central rows in all cases, no doubt as a result of the wider space between them; but in the case of pigeonpea, the border rows in the ridge and furrow system had a greater yield advantage over the central rows than in the other treatments. In chickpea there was a similar tendency (Table 48).

A possible reason for this effect is that in the ridge and furrow system, the missing of a row after every 4 rows meant that some of the border rows were on one side of a ridge, the other side of which was vacant. The pattern was as shown in Fig. 14. In strips 2 and 4, both border rows had an entire ridge to themselves, whereas in strip 3 they did not. Since cracks developed in the furrows, this would have meant that the border rows with a ridge to themselves would have had a larger soil volume to exploit than border rows on the sides of ridges which they shared with another row, since the crack in the furrows would have prevented the root system being able to grow through into the next ridge.

If this were true, then the border rows in strips 2 and 4 should have had a higher yield than the border rows in strip 3. In fact this formed out to be the case. In pigeonpea, the border rows in strips 2, 3, and 4 yielded 127, 107 and 137 g/row respectively, and in chickpea 279, 234 and 297 g/row respectively. This difference between the strips would not have been expected in the other land preparation treatments, and indeed it was not found (Table 49).

A statistical analysis for the data for border and central rows showed that with both crops the difference between strips, and the interaction between rows and strips were significant at the 1% level. The data for the rows are shown in Fig. 15.

These data focus attention on the role of cracking in segmenting the soil into blocks within which the development of the root system is confined. This could have important effects on post-rainy season crops, and different land preparation systems will give different patterns of cracking. However, this year's trial shows that there was little overall difference in yield due to the different land preparation systems are compared.

General Discussion

Unfortunately, the decimation of our main trial on cracking effects by the wilt disease means that the questions we had attempted to answer remain unanswered. Primarily, we were interested to find out whether different methods of land preparation, leading to different cracking patterns, could influence yield. If so, it might be possible to improve pigeonpea yields by taking into account methods of land preparation, and the way in which the rows are planted in

Table 47. Effect of different methods of land preparation on the yield (kg/ha) of pigeonpeas and chickpeas grown in the post-rainy season on Vertisol.

Treatment	Yield (kg/ha)	
	Pigeonpeas	Chickpeas
Flat (control)	781	1783
Flat (compacted)	800	1796
Broad beds	738	1877
Ridges and furrows	799	1854
SE	32	49

Table 46. Effects of different land preparations on the mean yields of border (B) and central (C) rows, and the difference between them. Data for pigeonpeas and chickpeas grown on Vertisol in the post-rainy season.

	Yield (g/3.5 M row)					
	Pigeonpeas			Chickpeas		
Treatment	Border	Central	B-C	Border	Central	B-C
Flat (control)	113	89	24	255	204	52
Flat (compacted)	117	90	27	259	204	55
Broad beds	109	83	26	270	215	55
Ridges and furrows	124	87	36	270	209	61
SE	5.1	3.6	3.4	7.7	6.0	5.3

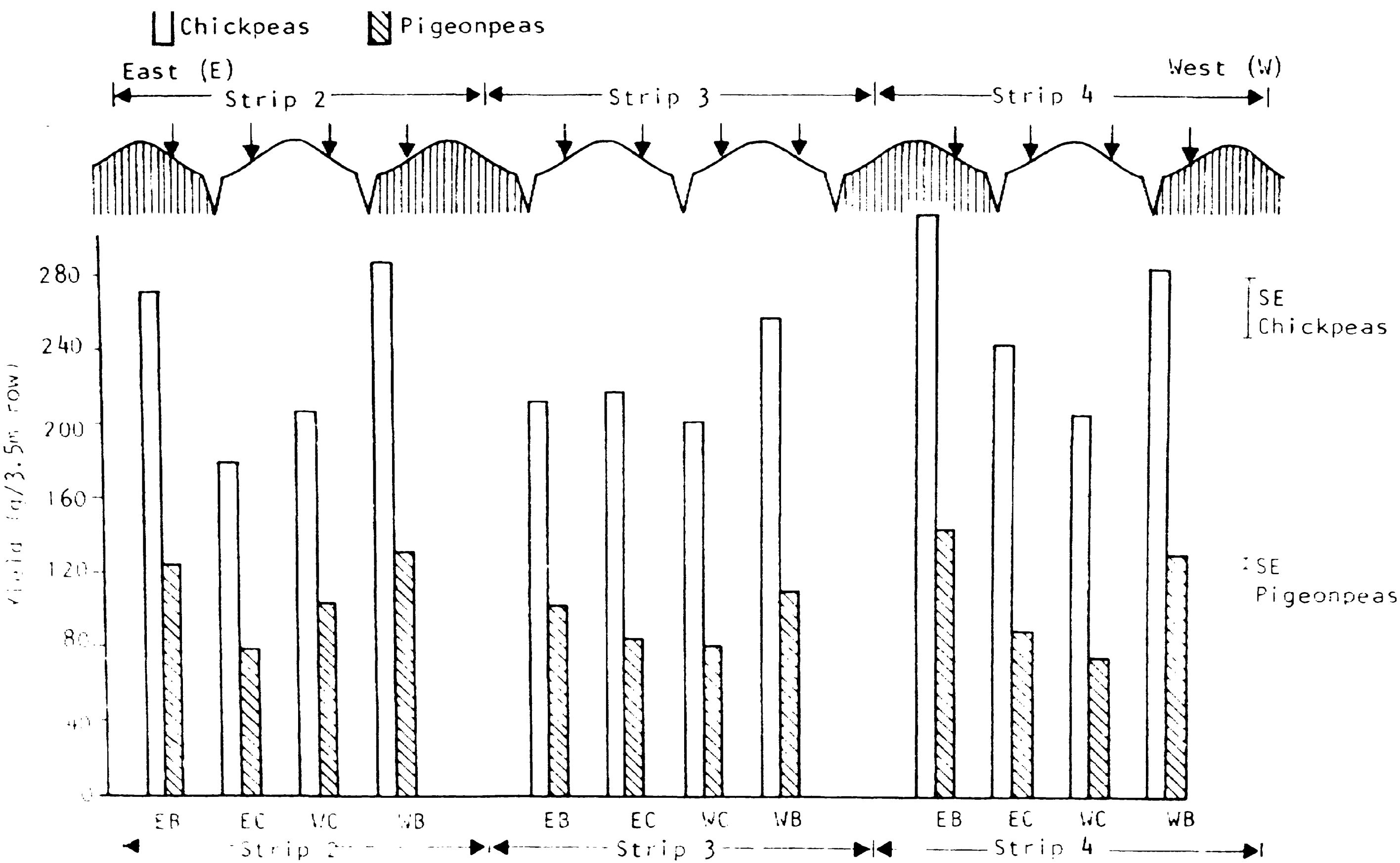


Figure 14 Yields of central (C) and border (B) rows of pigeonpeas and chickpeas grown on ridges and furrows on Vertisol in the post-rainy season.

Table 49. Mean yields of the two border and two central rows in strips 2, 3 and 4, with different land preparation systems. (The border strips 1 and 5 from each plot were discarded). In the ridge and furrow treatments, the border rows in strips 2 and 4 had a ridge to themselves, but in strip 3 shared a ridge with one of the central rows.

Treatment	Yield (g/3.5 M row)					
	Strip 2		Strip 3		Strip 4	
	Border	Central	Border	Central	Border	Central
Pigeonpeas						
Ridges and furrows	127	91	107	83	137	82
Flat (control)	114	87	112	93	111	86
Flat (compacted)	119	90	116	92	114	87
Broad beds	117	81	103	81	104	84
Chickpeas						
Ridges and furrows	279	201	234	209	297	224
Flat (control)	260	205	257	202	251	204
Flat (compacted)	266	206	265	201	246	206
Broad beds	273	233	273	197	264	222

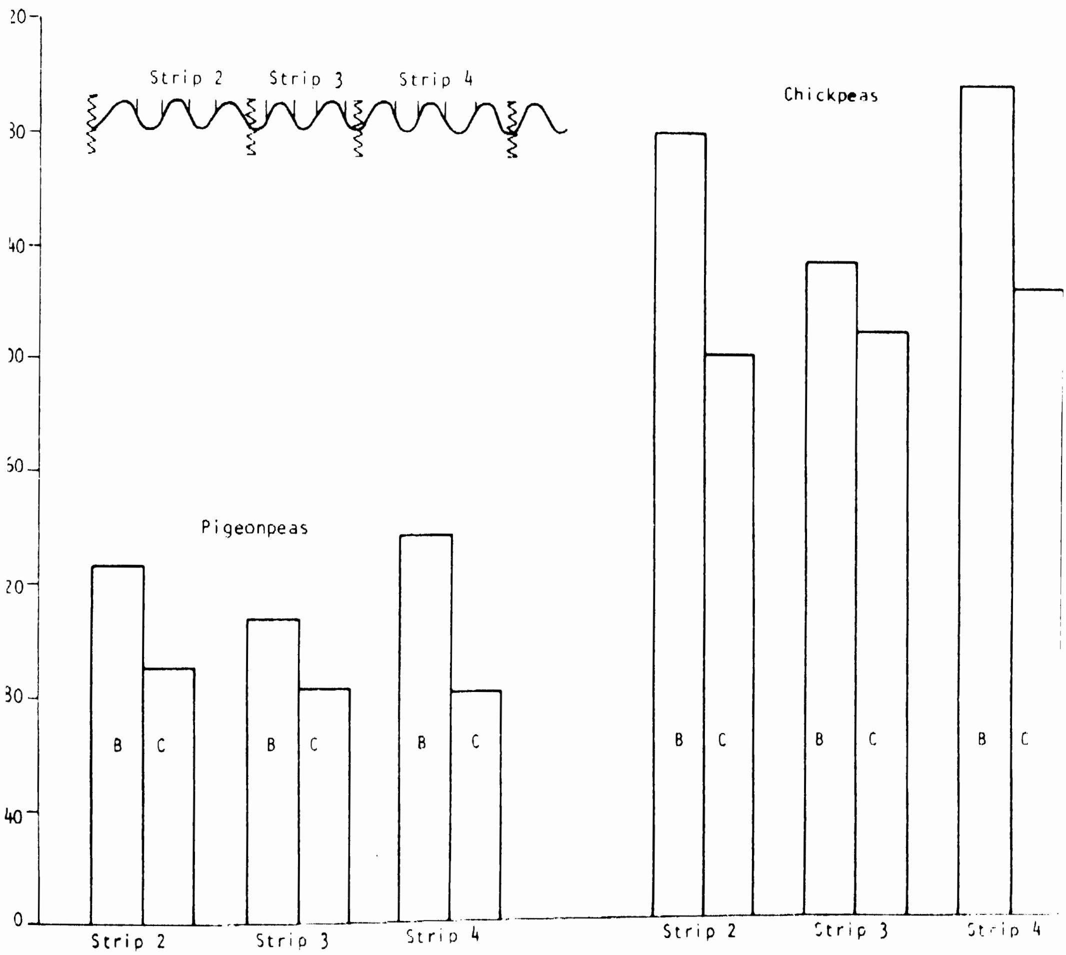


Figure 15. Yields (g/3.5m row) of border and central rows in strips 2-4 of pigeonpeas and chickpeas grown on 60 cm ridges and furrows.

relation to cracking zones.

However, again the difference between the yield of rows on the east and west rows on broad beds confirmed our observations last year, and can be interpreted in terms of a yield reducing effect of soil cracking, the differential effect being due to the east-west asymmetry of the root system.

On the other hand, the somewhat higher yield of rows on the west than the east sides of 75 cm ridges does not seem to fit in with this interpretation. It is also surprising that the root cutting treatments we imposed had no significant effects.

There is much we still do not understand about soil cracking and its effects on the yields of pigeonpea grown in the normal season on Vertisol, and only further investigations will be able to show whether or not an understanding of these effects can be put to use in increasing yields.

The results of the trial in the post-rainy season suggest that overall yield levels are not much affected by cracking patterns. But while this conclusion may be true of late-planted trials such as this one, where cracks develop while the plants are still young, with earlier plantings in which the root systems develop more extensively before cracking begins, there is likely to be more root damage, and different methods of land preparation and row planting may well result in different yields. Again, only further investigation will be able to shed light on this.

XIII. Some preliminary observations on the effect of the sterility mosaic disease on flowering

Sterility mosaic is an economically important disease of pigeonpea. As the name suggests the disease causes partial sterility in infected plants and flowering and podding are considerably delayed. The disease also causes a slight yellowing and mottling of the leaves. Physiologically, the delay in flowering due to this disease is of interest in relation to the control of flowering in pigeonpea. This study was therefore undertaken in collaboration with Dr. S.P.S. Beniwal, Pulse Pathologist to quantify the effects of infection at different stages of growth and with different sowing dates on sterility mosaic- susceptible, -tolerant and- resistant cultivars.

Materials and Methods

June sowing: Three cultivars, BDN-1 (susceptible), ICP-2376 (tolerant) and ICP-7035 (resistant) were sown in Vertisol in 12" earthen pots on 25-6-82 and kept outdoors. One plant per pot was raised. The pots were kept in isolation (near the Pulse Physiology laboratory in Manmool) away from the infected plants. The plants to be infected were inoculated with leaves from infected plants by the leaf-stapling technique at 10 (5-7-82), 30 (25-7-82), 60 (25-8-82), 80 (15-9-82) and 100 (5-10-82) days after sowing. There were 30 pots per treatment. The most recently infected plants were kept downwind of the already infected plants so that mites would be carried onto them in case they escaped artificial infection. Days to flower bud initiation and flowering were recorded for individual plants. Observations were made almost every day and the buds were identified visually rather than by dissection. Flowering was taken on the day on which the first open flower appeared on a plant. Stem dry weight and seed weight per plant were recorded at the time of maturity. Seed yield data are unfortunately unreliable owing to damage by parrots, and also by humans, who removed green pods, especially of cv. ICP-7035, which has large and tasty seeds.

August and October sowings: Experimental conditions were similar to those described above, and the same cultivars were used. Sowings were done on 23-8-82 and 28-10-82. Some plants were infected 10 days after sowing, and others kept as controls. In the August sowing, there were 45 pots per treatment, and in the October sowing 24.

Results and Discussion

Field observations of infected plants show that the sterility mosaic disease does not in fact result in complete sterility of the plants, but rather delays the onset of flowering.

In our experiment, infection of the susceptible cultivar, BDN-1, 10 days after sowing in June led to a very considerable delay in flowering of 74 days, and infection at 30 days delayed flowering by 47 days. However, infection at 60 days or more had no effect (Table 50).

The tolerant cultivar, ICP-2376, which develops 'ring spot' symptoms on the leaves after infection, showed a delay of 9-10 days in flowering and maturity. Infection at 30 days led to an even smaller delay, and subsequent infections had no significant effect. In the

Table 50. Effects of infection of susceptible (BDN-1), tolerant (ICP-2376) and resistant (ICP-7035) cultivars with the sterility mosaic disease at different stages of growth on flower bud initiation, flowering and maturity. Results are given in terms of days after sowing.

		(June Planting)		Days after planting			
Cultivar		Control	10 days	30 days	60 days	80 days	100 days
BDN-1	Bud initiation	64	120	80	64	64	64
	Flowering	86	160	133	88	89	86
	Maturity	163	227	195	166	163	163
ICP-2376	Bud initiation	69	75	75	69	69	69
	Flowering	95	106	103	92	91	94
	Maturity	166	176	167	166	166	166
ICP-7035	Bud initiation	74	75	75	74	74	74
	Flowering	134	143	151	136	132	132
	Maturity	192	210	221	191	188	187

		August planting		October planting	
		Control	10 days	Control	10 days
BDN-1	Bud initiation	55	100	60	100
	Flowering	73	135	88	123
	Maturity	137	188	110	127
ICP-2376	Bud initiation	56	61	62	64
	Flowering	77	87	91	92
	Maturity	139	166	116	125
ICP-7035	Bud initiation	66	68	76	86
	Flowering	94	99	98	103
	Maturity	161	178	121	124

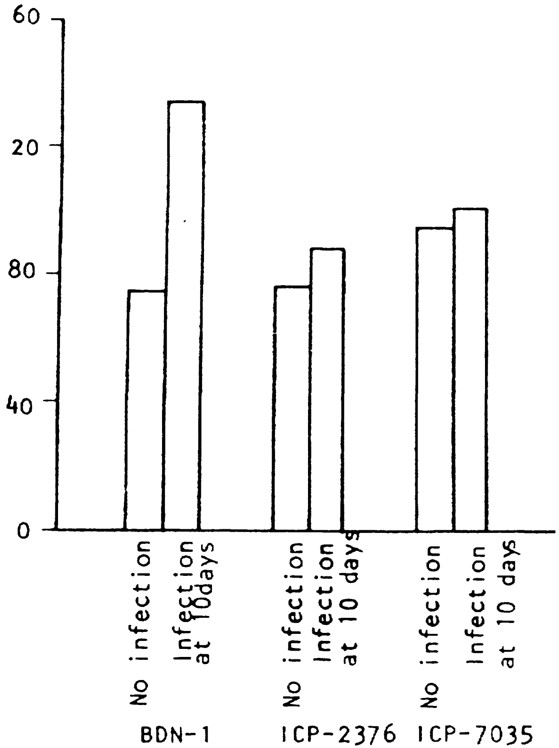


Figure 16. Effect of SMD infection on days to flowering of different cul-

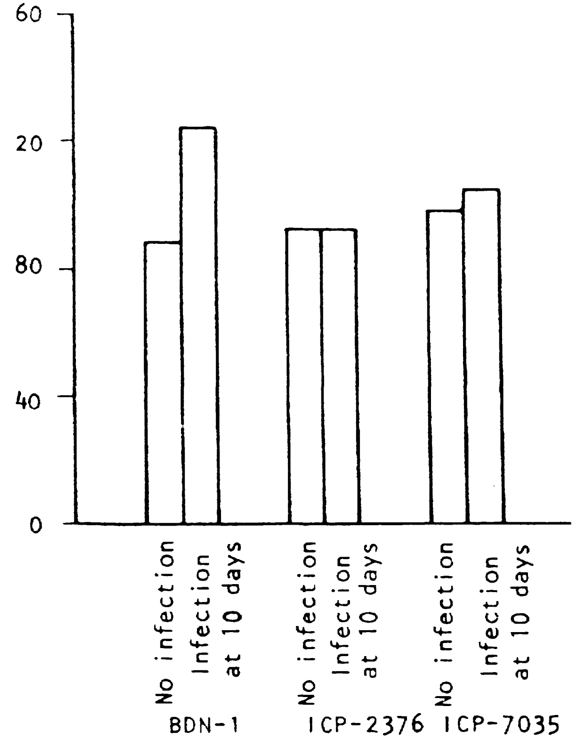


Figure 17. Effect of SMD infection on days to flowering of different cultivars in

resistant cultivar also, infection at 10 and 30 days also had a small effect in delaying flowering and maturity. In the August and October plantings, infection of cv BDN-1 at 10 days also led to long delays in flowering, of 62 and 35 days, respectively; infection of the two other cultivars had much less effect, and delayed flowering by only 10 days (Table 50).

Studies on flower bud initiation, (by visual observation, rather than by dissection) like flowering showed that, it was delayed by infections in the early stages of growth. In the susceptible cultivar, BDN-1, infected at 10 days, it was delayed by 56 days as compared with the healthy control. Flowering, however, was delayed by 74 days, so it seems that the sterility mosaic disease not only retarded the initiation of flower buds, but also retarded their development. A similar pattern was apparent in the other two cultivars, and also in the August sowing (Fig. 16). It is possible that some of this delay in flowering was due to the cooler temperatures that followed flower bud initiation. Delayed bud initiation meant that the development of these buds with flowers took place in cooler weather, but this was probably also a direct consequence of the infection, since even when delays in flower bud initiation were quite short, 3 or 4 days, there was a disproportionate delay in flowering.

The data on seed yield were rather variable, and perhaps not too reliable. It is difficult to believe, for example, that infection at 100 days could have led to a large increase in seed weight in cv BDN-1 (Table 51). Moreover, the seed yield data for cv ICP-7035 are distorted as a result of human interference - the large seeds of this cultivar taste good, and unfortunately pods were plucked from these plants by passing labourers. The controls suffered most since they were nearer the path. Nevertheless, in spite of all the reservations with which this data has to be treated, it does show fairly clearly that infection in early stages of growth not only delayed flowering and podding in the susceptible cv BDN-1, but also led to a severe reduction in yield. A comparable reduction did not occur in the tolerant cultivar ICP-2376.

The data on stem weight at the time of harvest indicate that infection of the plants at 10 and 30 days after sowing led to considerable reductions in growth of 40-50%. This effect was apparent to a similar extent in all 3 cultivars (Table 51). These results are suprising. Although in the case of the susceptible cultivar, the yellow blotcher on the leaves might well be expected to result in reduced photosynthetic efficiency, and to some extent the ring spots on the leaves of the tolerant cultivar, no effect would have been expected in the resistant cultivar. It is possible that these results are due to chance effects. Due to the large variability from plant to plant, but the pattern seems too consistant to be explained away in this way. Another possibility is that the environment when the infected plants were kept was less favourable for growth than when the uninfected plants were kept. Although in both cases, they were sufficiently far from building not to be shaded during the day, it is possible they were subject to other influences which affected their growth - perhaps differently exposed to wind. It is even possible that the infected plants were not watered as regularly, although we think that this has in fact carried out reliably and in the same way

Table 51. Seed yield and stem dry weight (g/plant) of susceptible, tolerant and resistant pigeonpea cultivars infected with sterility mosaic disease at different times after sowing in June

Cultivar	Yield or stem weight (g/plant)	Control	Infected (days after sowing) 10	30	60	80	100
BDN-1	Yield	12.9	3.9	4.9	9.4	14.3	24.9
	Stem weight	46.3	26.4	26.4	41.3	40.3	50.7
ICP-2376	Yield	19.2	17.1	14.7	19.9	19.2	26.6
	Stem weight	46.7	27.6	22.9	35.9	40.3	49.7
ICP-7035	Yield	3.1	6.9	8.1	14.7	13.1	8.0
	Stem weight	73.9	40.7	42.2	69.3	62.6	67.3

SE for comparing means within a cultivar
for yield 1.8
for stem weight 6.2

at both locations.

But it is also possible that the sterility mosaic disease really does reduce the growth of the resistant cultivar, by infecting it in such a way that there are no visible symptoms. This requires further investigation.

These findings taken together show that in the susceptible cultivar, the sterility mosaic disease had a specific effect on reproductive growth - not, however, by preventing it altogether, but by leading to a delay in flower bud initiation, and to a delay in flower development from seeds, and to a reduction in yield. The way in which the disease brings this about is completely unknown, but it is of considerable physiological interest. Fundamental studies of this problem, for example at a university, might shed valuable light on the mechanism of control of flowering in pigeonpea, and of the factors controlling the balance between vegetative and reproductive growth.

XIV. Rabi Kharif Rabi Perennial Cropping System

The feasibility of a perennial cropping system starting in the post-rainy (rabi) season, and continuing until the following rabi season was demonstrated in an experiment we conducted at Sangareddy (PPR 1981-82, Chapter XI). This involved a wilt-resistant and sterility mosaic tolerant cultivar, ICP-1-6. The yield obtained in the second post-rainy season was similar to that obtained from a normal crop sown at the beginning of the rainy season. In order to test the repeatability of these results, a similar experiment was established at ICRISAT Center in a fairly large area (about 0.3 ha) both in the pesticide-free part of the farm, and in another area in which spraying is permitted. In addition, small tests were conducted to compare the potential of several wilt and sterility mosaic resistant cultivars in this system.

Materials and Methods

Large plot trial with cv ICP-1-6: Cv ICP-1-6 was sown on 150 cm broad beds and furrows on 21-9-82 (sowing 1) and 28-9-82 (sowing 2) on Vertisol field BUS-6B in the pesticide free area of the farm, and on 28-9-1982 on a Vertisol field BR-4. Sowing was done in rows 30 cm apart using a tractor mounted seeder. Plant to plant distance was 6-10 cm. There were four rows on each broadbed. The area sown was 0.38 ha in BUS-6B and 0.29 ha in BR-4. No irrigation was given either at the time of sowing or subsequently. No fertilizers were applied to these fields.

One hand weeding was done on 10-11-82 in BR-4. The crop reached 50% flowering on 28-12-82 in BR-4 and 6-1-83 in BUS-6B. A spray of endosulfan was given on 14-1-82 in BR-4. The crop matured on 22-2-83 in BR-4 and was harvested on the same day, and matured on 28-2-83 in BUS-6B and was harvested on 3-3-83.

At maturity, in one part of each field, 18 (6 x4 m) plots were marked out in which the crop was harvested in different manners, by pod picking, and ratooning at 30 or 15 cm above ground level. These treatments were randomised in six replications. Percent mortality recorded at maturity and in April and June is given in Table 52. The remaining areas (0.24 ha on BR-4 and 0.33 ha on BUS-6B)of the fields were harvested uniformly by ratooning plants at 30 cm plant height. Insect damage to pods was monitored by entomologists.

Cultivar comparision: These trials were planted on 4-10-82 adjacent to above trials in the same fields. Six cultivars, ICP-8858, (ICP-1-6 selection by Pathologists), ICP-1-6 (Breeders' selection), ICP-8861, -8859, -8860, and -7119 were sown at 30 x 10 cm spacing by hand on 150 cm broadbed and furrows. These

Table 52. Plant stand and mortality at the time of harvesting the rabi crop, and effect of different methods of harvesting on the subsequent mortality of cv ICP-1-6 grown in fields BR-4 and BUS-6B.

Harvest method	Plant stand at harvest	Plant mortality		
		At harvest	On April 15	On June 15
Field BR-4 (harvested Feb 22)				
Pod picking	30	8.5	31.0	53.3
Ratooning at 30 cm	30	7.5	41.4	67.3
Ratooning at 15 cm	30	8.0	64.9	87.2
Field BUS-6B (harvested March 3)				
Pod picking	29	0.2	2.6	10.2
Ratooning at 30 cm	28	0.3	4.9	15.1
Ratooning at 15 cm	27	0.4	7.1	21.9

Table 53. Phenology of sterility mosaic resistant cultivars grown in rabi-kharif-rabi trial in fields BR-4 and BUS-6B. Days after sowing as given in parenthesis.

Cultivar	Date of 50% flowering		Date of maturity	
	BR-4	BUS-6B	BR-4	BUS-6B
ICP-1-6	6-1(94)	18-1(106)	28-2(147)	12-4(190)
ICP-8858	30-12(87)	18-1(106)	24-2(143)	12-4(190)
ICP-8861	4-1(92)	18-1(106)	22-2(141)	12-4(190)
ICP-7119	4-1(92)	10-1(98)	22-2(141)	12-4(190)
ICP-8859	18-1(106)	24-1(112)	23-3(170)	12-4(190)
ICP-8860	6-1(94)	24-1(112)	23-3(170)	12-4(190)

cultivars have been identified by ICRISAT Pulse Pathologists as resistant or tolerant to sterility mosaic disease, and also to the wilt disease. There were four rows on each broadbed and furrows and the plot size for each cultivar was 3 x 4 sq.m. There were three replications. The design of the trial was RBD. No irrigation was given. Other operations such as weeding and spraying were done as in the above experiments.

Days to 50% flowering and maturity are given in Table 53. Harvesting was on 3-3-83 in BR-4 and on 15-4-83 in BUS-6B.

Results and Discussion
Yield of cv ICP-1-6:

In field BR-4, the mean yield of cv.ICP-1-6 harvested by different methods (pod picking, ratooning at 30 cm and at 10 cm) was 673 kg/ha, and the mean yield in the remaining 0.24 ha was 660 kg/ha. This is a fairly low yield for an early planted rabi crop. For example, the mean yield obtained this year with a late planted rabi pigeonpea crop in another field (BP-11C) was 780 kg/ha)(Chapter 12), and September or October plantings usually give higher yields than November plantings (PPR 1980-81, Chapter VIII).

One reason for the relatively low yield could be insect damage, which was condiserable in spite of the fact that the crop was sprayed with insecticide on one occasion. An examination of samples by the Pulse Entomologists revealed that, on average, 32% of the pods were damaged by insects.

A further reason for the low yield could be that pigeonpeas had been grown in this field the previous year, and hence there could had been a build-up of nematodes and/or other parasites in the soil. This seems quite likely in view of the higher mortality in this field than in BUS-6B (see below) and rather patchy and relatively poor growth of this crop in the following kharif season.

In field BUS-6B, the growth of the crop was generally better than in BR-4, but the yields were lower. In the plots in which different harvest methods were compared, the mean yield was 460 kg/ha. In the large plots sown on September 21, the mean yield was only 74 kg/ha; in the large plot sown on September 28 the mean yield was 370 kg/ha.

These low yields are largely explicable in terms of insect damage, which was very heavy. No pesticides were applied, since this trial was grow in the pesticide-free area of the farm. Pod damage assessments by the Pulse Entomologists were 72% in the first sowing and 61% in the second sowing. The insect damage, however, had more severe effects than these figures suggest, since many flowers were eaten by *Heliothis* caterpillars, and pod set was reduced as a result. The later maturity of this crop than in field BR-4 was probably due mainly to delayed pod-setting as a result of insect damage to many of the flowers.

Survival of the plants

There was almost no plant mortality in field BUS-6B at the time of first harvest (Table 52). However by mid-April, a few of the plants had died. The extent of mortality was influenced by the way the first flush had been harvested - with pod picking mortality was least (2.6%) and was most after ratooning close to the ground (7.1%). Further death had occurred by mid-June, with 10.2% in the plants from which pods had been picked, and 21.9% in those ratooned close to the ground (Table 52).

In field BR-4, mortality was considerably higher - about 8% at the time of harvest of the rabi crop, and over 50% by mid-June. Again, there was least mortality after pod picking, and most after ratooning close to the ground; indeed by June the mortality in the latter plants was as high as 87% (Table 52).

In our previous trial at Sangareddy, ratooning close to the ground also led to more mortality than ratooning higher up (PPR 1981-82, Chapter XI), although the differences were rather small (57% mortality as opposed to 52%). The reason for the higher mortality in field BR-4 probably include damage by nematodes and other soil parasites. The greater survival of the plants in BUS-6A could also be related to their low yield due to insect damage, since the reduced development of reproductive sinks could have led to more assimilates being diverted in vegetative structures and roots, making the plants better able to survive the hot, dry summer.

In spite of the high mortality in field BR-4, there was still, on average, a higher plant population than is usually employed for a raniy season crop (48,000 plants/ha), because the density at which the rabi crop was sown was so much higher (around 350,000 plants/ha).

However, these results indicate that since mortality is likely to be increased by ratooning the plants close to the ground, the first crop should be harvested by cutting the plants as high up as possible, i.e. just below the lowest pod-bearing nodes. Although pod-picking gives still lower mortality, this is probably too time consuming to be feasible in farmers' fields.

The surviving plants put on good growth with the onset of the monsoon rains. However in field BUS-6B a number of the plants (up to 20%) showed symptoms of sterility mosaic disease, and as a precaution against the disease spreading to other pigeonpeas grown nearby, the experiment was terminated in June 1983. In field RP-4B there was much lower disease incidence. The plants were sprayed in June as a precautionary against the build up of mites on the plants, because they act as vectors of the sterility mosaic disease. Data on the yield of of this crop will be given in our 1983-84 report.

Table 54. Yield (kg/ha) and plant stand at the time of harvest of the rabi crop from sterility mosaic resistant cultivars grown in fields BR-4 and BUS-6B.

Cultivar	Yield (kg/ha) BR-4	Yield (kg/ha) BUS-6B	Plants per sq.m. BR-4	Plants per sq.m. BUS-6B
ICP-1-6	420	93	15	22
ICP-8858	483	92	19	26
ICP-8859	288	101	15	22
ICP-8860	146	9	17	21
ICP-8861	340	46	12	19
ICP-7119	332	16	11	12
Mean	335	60	11	20
SE	95	147	2	3
CV%	49	43	17	22

Comparison of different cultivars:

In field BUS-6B yields were extremely low - an average of only 60 kg/ha (Table 54). This was due to very heavy insect attack, heavier than in the other plots in this field, probably because of the later planting of this trial. In BR-4 yield levels were higher (mean 335 kg/ha) than in BUS-6B, but lower than in the other plots in this field. One reason for this may be the relatively poor plant stand due to poor establishment (Table 54), and the fact that this trial was planted in a part of the field when growth was generally poor. The highest yields were obtained from cvs. ICP-1-6 and ICP-8858, which have both been selected from a common source.