Pulse Physiology
Progress Report 1981-82

Part I
Pigeonpea Physiology

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PIGEONPEA PHYSIOLOGY

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* November 20, 1981 - January 4, 1982 and November 3, 1982 - January 3, 1983.

** From 1.10.1982

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CONTENTS

S U M M A R Y

I. Climate and soil:

This year's rainfall at ICRISAT was higher (1155 mm) than the long term average of 800 mm (1901-1970) and fairly well distributed during the rainy season.

II. Effect of planting date on pigeonpea growth:

The growth of four cultivars, UPAS-120, T-21, C-11 and NP(WR)-15 was compared under irrigated conditions in monthly plantings from April to February.

The dry weights of the plants at 50 and 80 days after sowing were markedly affected by date of sowing. The plants grew most when sown in April and May when weather was warm, and least in November and December when weather was cool, indicating an important influence of temperature. Relatively poor growth occurred when mean minimum temperatures were below 22 °C.

III. The yield potential of medium duration pigeonpeas:

Yields of medium maturity cultivars in various Pulse Physiology, Pulse Entomology, Pigeonpea Breeding and Farming Systems trials have rarely exceeded 2 tonnes/ha. Yields on Alfisols are generally lower than Vertisols. Moisture availability and mineral nutrients do not appear to be severe limiting factors, since with ample supplies of these inputs, a maximum yield of only 2300 kg/ha could be realized from cv. ICP-1-6 in Vertisol. The low yields of medium maturity genotypes may be primarily related to climatic factors, particularly the low temperatures prevailing during their reproductive phase.

IV. The yield potential of extra-early pigeonpeas at Hissar:

Yields as high as 3400 kg/ha were obtained at Hissar with the best cultivar, ICPL-87, in a relatively short period. The crop growth rate and per day grain production were much higher at Hissar for the extra-early genotypes than for medium maturity genotypes at Hyderabad, probably because of the warmer weather at Hissar during the growing period.

V. The yield of rabi pigeonpeas grown with frequent irrigation:

The mean yield of rabi pigeonpeas with frequent irrigation and high inputs of nitrogen and phosphorus was only 480 kg/ha. One possible reason for this low yield may have been waterlogging due to excessive irrigation.

VI Screening for tolerance to soil salinity:

The performance of 79 pigeonpea lines was compared with tolerant and susceptible checks in a naturally saline-alkaline soil. Twenty seven lines were identified by visual scoring as being at least as tolerant as the tolerant check, cv. C-11.

A pot screening method using artificially salinized soil was developed in which the tolerant cv. C-11 and the susceptible cv. HY-3C showed a satisfactory differential response at the seedling stage.

VII. Screening for waterlogging tolerance:

Fifty two lines including 46 Phytopthora blight resistant lines were screened for waterlogging tolerance in pots along with two checks cv. BDN-1 (tolerant) and HY-3C (susceptible) during March. Thirteen Phytopthora blight resistant lines and one advanced breeding line survived better than the tolerant check.

VIII. Selection for physiologically annual pigeonpeas:

Dead plants free of pathological symptoms were identified at the time of maturity of material derived from seeds of cvs. BDN-1 and ICP-1-6 which had been treated with chemical mutagens. Progenies from these plants are now being tested for annuality.

IX. Second harvest yields of intercropped pigeonpeas:

The second harvest yield of intercropped pigeonpeas on an Alfisol watershed was 322 and 211 kg/ha with and without irrigation respectively.

Effect of soil cracking on the yield of pigeonpea:

Evidence that cracking in Vertisol may reduce pigeonpea yields was obtained from comparing rows grown on the sides and in the centre of broadbeds running north-south. Cracking predominantly occurred in the furrows and affected the yields of the side rows adjacent to them. The central rows, which were further away from the furrows yielded significantly more than side rows.

Yield differences in the side rows on the east and west sides of the broadbeds were observed, which could best be ascribed to differential root pruning by cracks resulting from an asymmetric root distribution as the east and west sides of the plants.

Rabi-kharif-rabi pigeonpeas: a perennial cropping system:

In a trial conducted at Sangareddy in conjunction with Andhra Pradesh Agricultural University, cv. ICP-1-6, which is resistant to wilt and tolerant to sterility mosaic disease, successfully gave a kharif and a further ratoon crop from a previously established rabi crop, enabling three harvests of grain to be taken in succession from one planting. This opens up the possibility of taking a crop of pigeonpea in Vertisols which are currently left fallow during the kharif season by pre-establishing a rabi crop and carrying it through to the next kharif after ratooning or podpicking.

XII. Response of pigeonpea grown in rainy and postrainy seasons to irrigation:

Three irrigations applied during the mid vegetative, late vegetative and early reproductive phases of rabi pigeonpeas led to an increase in growth and yield. Two irrigations applied during the reproductive phase of solecropped pigeonpea sown at the beginning of the rainy season led to an increase in yield without increasing total dry-matter. By contrast, irrigation had no beneficial effect on the yield of intercropped pigeonpea.

XIII. Preliminary observations on the shoot water potential of pigeonpeas:

Pigeonpeas appear to maintain a high shoot water potential even when they are expected to be suffering from waterstress, unlike chickpeas and other crop in which shoot water potential reaches a minimum around soon after mid-day. The shoot water potential of pigeonpeas grown both in the normal and postrainy season continued to decline throughout the day.

INTRODUCTION

Meteorological and soil data:

In this report, we present the results from work carried out between June 1981 and May 1982.

The meteorological data for 1981-82 collected at ICRISAT Agroclimatological observatory are shown in Fig. 1. This year rainfall (1155 mm) was much greater than long term (1901-70) average (800 mm) and farily well distributed during rainy season (Table 1). The cessation of rainfall occurred in October and the period following this until April was dry, except for some scanty rainfall in November.

The meteorological data from June 1981 to December 1981, collected at Hissar Agroclimatological observatory are shown in Table 2.

Experiments were conducted at ICRISAT Center on Vertisol fields BW-3, BW-5, BP-14A, BL-2B, BS-8C and on Alfisol fields RP-4B and RCE-18 and at ICRISAT Sub-center at Hissar. The planting dates and fertilizer used are indicated in the Materials and methods section of each experiment.

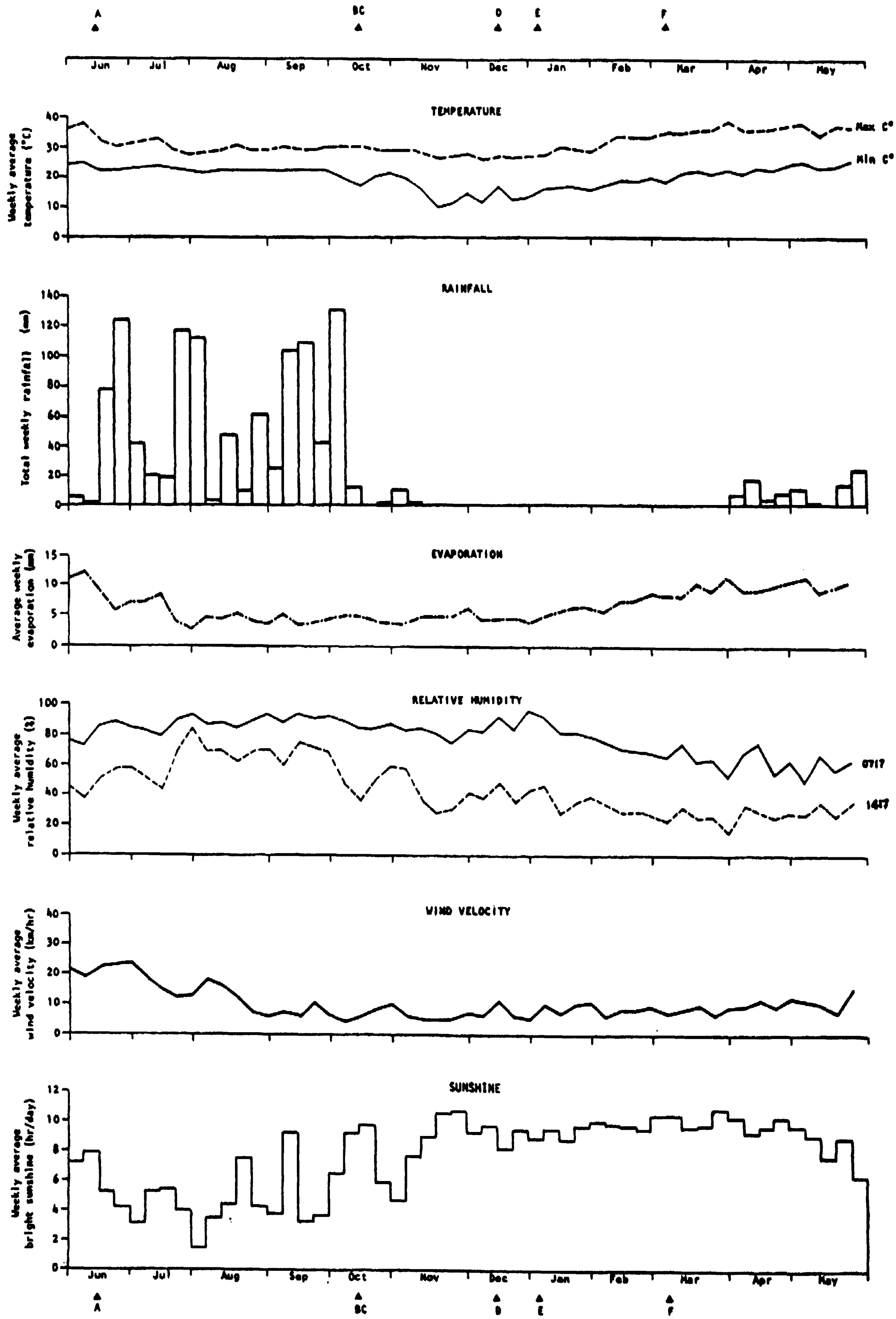
Soil samples for analyses of pH, electrical conductivity, available phosphorus were taken at the time of planting. Details of analyses are given in Table 3.

All sowings were done by hand. Two seeds per hill were planted and the plants were thinned 2-3 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 the Plant Protection Unit.

In the previous year pigeonpea was grown in Alfisol field RCE-18, sorghum-pigeonpea intercrop in field RP-4B, and groundnut in field BP-14A. In the other fields, pigeonpea followed a sorghum crop. The fields in which a rabi crop was sown were left fallow during the kharif season.

We have referred to our previous Pigeonpea Physiology Reports as PPR 1975-76, PPR 1976-77 etc. We have also referred to ICRISAT Pigeonpea Breeding, Pigeonpea Entomology, Farming Systems Research Program and Chickpea Physiology Reports in a similar manner.



A. Sowing rainy season crop
B. Sowing post rainy season crop
C. Flowering rainy season crop
D. Harvesting rainy season crop
E. Flowering post-rainy season crop
F. Harvesting post-rainy season crop

Figure 1. Meteorological data for ICRISAT Center (June 1981 to May 1982).

This report is not a formal publication but a summary of work in progress. It is intended for limited circulation and should not be cited.

Table 1. Summary of rainfall (mm) at ICRISAT Center with departure from the long term average (1901 to 1970) for Hyderabad.

Year	Monthly rainfall												Total
	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	
1981-82	203	209	218	287	155	2	0	0	0	0	34	47	1155
1901-70	115	171	156	181	67	23	6	6	11	13	24	27	800
Difference	+88	+38	+62	+106	+88	-21	-6	-6	-11	-13	+10	+20	+355

Table 2. Meteorological observations at Hissar from June 1, 1981 to December 31, 1981.

	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall (mm)	94.8	170.6	58.7	27.2	0	60.7	0
Average max. temp. (°C)	42.8	34.2	35.5	36.2	33.7	25.9	22.6
Average min. temp. (°C)	26.5	26.7	25.7	23.1	15.2	10.8	4.7
Average humidity 0727 h (%)	51	85	82	80	84	89	92
Average humidity 1427 h (%)	22	67	56	43	24	39	30
Average wind velocity (km/h)	9.6	8.1	5.7	4.7	3.2	3.5	1.7
Average sunshine (hours/day)	7.8	5.1	8.6	8.9	9.6	8.0	8.6
Average daily evaporation (mm/day)	12.9	5.1	6.1	6.3	5.0	2.6	1.8

Table 3. Soil analysis for the fields used for pigeonpea physiology experiments in 1981-82.

Soil and field No.	Depth of soil (cm)	pH (in 1:2 soil water extract)	EC (in 1:2 soil water extract) (mmhos/cm)	Available P (ppm).
Black (Vertisol)	0 - 30	7.38	0.33	4.2
Field BP-14A	30 - 60	7.41	0.34	0.5
(Kharif Trial)	60 - 90	7.35	0.32	1.1
	90 -120	7.27	0.30	0.5
Black (Vertisol)	0 - 30	8.58	0.22	7.0
Field BP-14A	30 - 60	8.67	0.25	1.4
(Rabi Trial)	60 - 90	8.72	0.28	1.4
Black (Vertisol)	0 - 30	8.36	0.39	3.1
Field BW-5	30 - 60	8.33	0.48	3.2
	60 - 90	8.95	0.52	1.7
	90 -120	8.82	0.70	2.1
Black (Vertisol)	0 - 30	7.36	0.33	2.0
Field BL-2B	30 - 60	7.45	0.32	0.8
	60 - 90	7.74	0.26	1.0
Red (Alfisol)	0 - 30	7.47	0.36	7.9
Field RP-4B	30 - 60	7.47	0.31	5.1
	60 - 90	7.38	0.35	10.2
Red (Alfisol)	0 - 30	7.76	0.23	4.2
Field RCE-18	30 - 60	7.30	0.28	1.5
	60 - 90	7.50	0.24	1.0

II. EFFECT OF PLANTING DATE ON GROWTH

We investigated the effect o ing date on the growth of pigeonpea in order to obtain a better idea quantitative responses to environmental factors, particularly tempe . We compared 4 cultivars, of different duration groups, in mont antings from April to February. The plants were grown with frequent irr on, to minimize the effects of water stress. Our primary interest in studying their vegetative growth over the first 50 days, before flow began.

Materials and methods

The experiment was conducted in Alfisol field RCE-18 at ICRISAT Center. The trial was laid out in a split plot design with 3 replications, with sowing dates as main plots and cultivars as subplots (size 5 x 5.25 m). The sowings were carried out at monthly intervals from 15 April 1981 to 15 February 1982.

The 4 cultivars used in this study were chosen to provide diversity in maturity type. These were: UPAS-120 (extra early), T-21 (early), C-11 (medium) and NP(WR)-15 late.

Plantings were done at 37.5 x 20 cm spacing on 75 cm wide ridges and furrows. Irrigation was applied at monthly intervals at the time of each new planting, except in August and September when it was unnecessary, due to rains. Additional irrigations were given as and when necessary.

To determine crop growth rates (CGR), all the plants were harvested from a 3.75 m^2 area, at 50 and 80 days after sowing. Fresh weights of the shoots of these plants were recorded. A random sample of five plants was drawn from it, and their fresh wiehgt recorded. Counts of plants in the original sample was also made before discarding it. The 5 plant subsample was used for observations on leaf number, plant height and branch number. The fresh weights and oven dry weights of this subsample was used to calculate the dry weights of the entire harvested samples from their fresh weights.

The dates of 50% flowering and maturity were recorded for each subplot, and yield and yield components were recorded at harvest. Unfortunately a high incidence of Phytopthora blight led to the death of up to 80% of the plants in the April-September plants, and so reliable yield data could not be obtained. For the same reason, insufficient plants could be harvested from the August planting for crop growth rate determinations.

Meteorological observations we   otained from ICRISAT Agroclimatology Section. Hourly temperature readin   ere averaged to calculate mean daily temperatures. Further calculations fiele carried out to obtain the mean values for the 50-day sampling peric of maximum, minimum and mean temperatures, solar radiation and open pan aporation.

Results and discussion

Effects on flowering:

The effects of sowing date on flowering were similar to those observed previously at ICRISAT Center (Pigeonpea Breeding Report 1974-75, p. 78; 1975-76, p. 99). Cultivars differed most in the number of days to flowering in the April sowing (Fig. 2), and in all cultivars flowering occurred sooner in the subsequent sowings. These responses reflect both the effects of decreasing daylengths, and also lower temperatures.

In cv. C-11, planted in April, 50% flowering occurred by 25.8.81, almost a month before the equinox in September, which is surprisingly early for a medium cultivar (Table 4). In 1974-75, cv. ST-1 planted in April did not flower until 20.9.81 and plants of the same cultivar in January, February and March sowings all flowered on 14.9.81 (PPBR 1974-75, p. 81). Perhaps cv. C-11 differs significantly in its photoperiod and temperature response from other medium cultivars such as cv. ST-1; or perhaps the dip in temperature in late July and early August (Fig. 1) favoured flowering. In pigeonpeas, cooler temperatures seem to overcome to some extent the effects of long days in delaying flowering (PPBR 1975-76, p. 98).

The minimum number of days to flowering, in cv. UPAS-120 planted in January, was 54 (Table 4). Hence the samplings taken at 50 days represent vegetative growth in all cases.

Growth:

The dry weights of the plants at 50 days after sowing, expressed on a unit area basis, showed a striking difference with planting dates. The plants grew most in the April and May plants, and least in the November and December plantings (Table 5). The dry weights of the latter were only about a tenth of the former. A similar pattern can be seen in the dry weights at 80 days after sowing (Table 6). Mean data for plant height, branch number and LAI at 50 days also demonstrate the strikingly greater growth in the earlier sowings, and the much reduced growth in November and December sowings (Table 7).

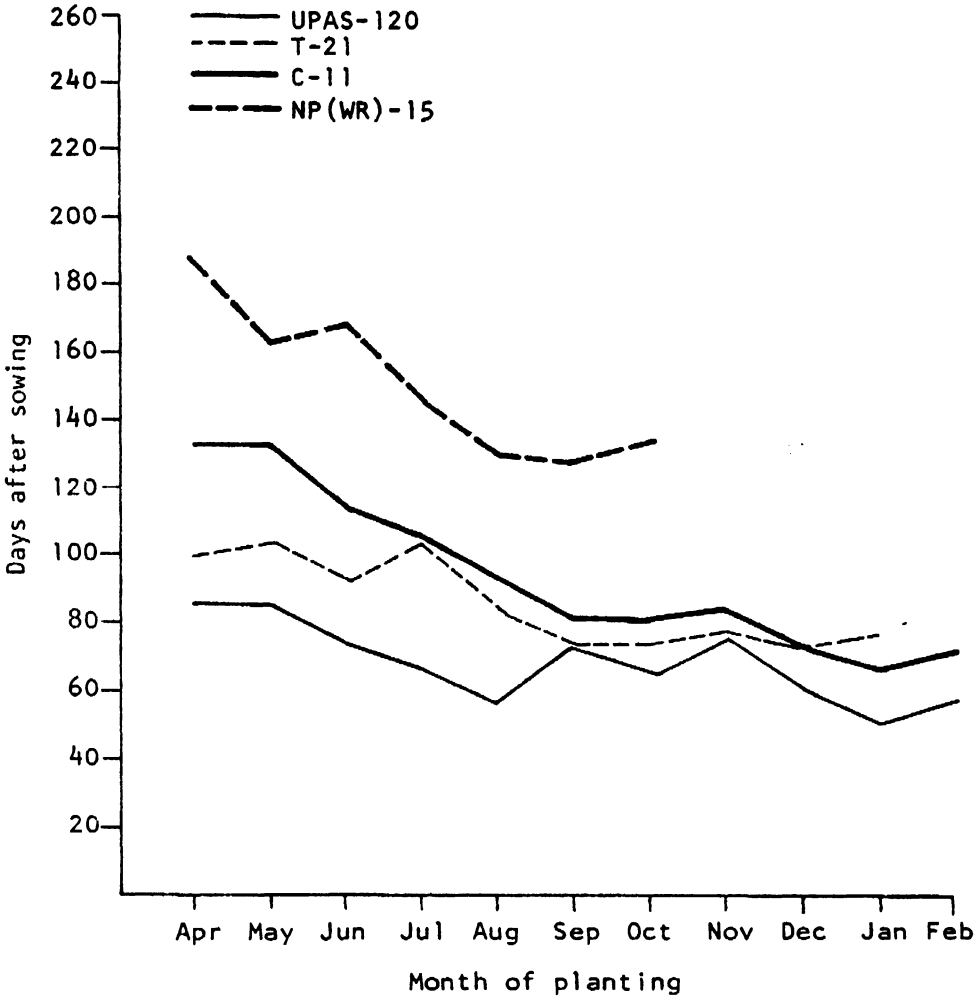


Figure 2. Days to 50% flowering of 4 cultivars at different dates of sowing.

Table 4. Dates of 50% flowering of 4 pigeonpea cultivars planted at monthly intervals at ICRISAT Center (Days to 50% flowering are shown in brackets).

Planting date	Cultivar							
	UPAS-120		T-21		C-11		NP(WR)-15	
15.4.81	9.7.81	(85)	23.9.81	(99)	25.8.81	(132)	20.10.81	(188)
15.5.81	8.8.81	(85)	25.8.81	(102)	23.9.81	(131)	25.10.81	(163)
15.6.81	27.8.81	(73)	15.9.81	(92)	10.10.81	(117)	1.12.81	(169)
15.7.81	20.9.81	(67)	26.10.81	(103)	30.10.81	(107)	9.12.81	(147)
15.8.81	12.10.81	(58)	5.11.81	(82)	20.11.81	(97)	24.12.81	(131)
15.9.81	25.11.81	(71)	29.11.81	(75)	5.12.81	(81)	21.1.82	(128)
15 10.81	20.12.81	(66)	28.12.81	(74)	5.1.82	(82)	9.2.82	(117)
15.11.81	30.1.82	(76)	2.2.82	(79)	9.2.82	(86)	29.3.82	(134)
15.12.81	15.2.82	(62)	27.2.82	(74)	1.3.82	(76)	*	
15.1.82	10.3.82	(54)	24.3.82	(68)	1.4.82	(76)	*	
15.2.82	15.4.82	(59)	28.4.82	(72)	*		*	

* Flowering had not occurred by 4.5.82 when the experiment was terminated.

Table 5. Dry weight at 50 days after sowing of 4 pigeonpea cultivars sown at monthly intervals.

Sowing date	Shoot dry weight (g/m^2)				Mean
	Cultivar				
	UPAS-120	T-21	C-11	NP(WR)-15	
April	23.3	50.6	59.8	26.7	40.1
May	36.9	50.7	47.0	34.7	42.3
June	11.3	31.5	28.7	20.5	23.0
July	6.5	12.9	9.2	12.4	10.3
September	7.5	5.6	6.6	8.9	7.2
October	8.7	12.0	11.7	9.6	10.5
November	2.8	4.2	4.4	4.3	3.9
December	4.9	5.3	4.8	4.6	4.9
January	9.8	10.3	10.7	10.3	10.3
February	8.4	11.6	9.9	11.1	10.3
SE					± 3.04
Mean	12.0	19.5	19.3	14.3	
SE		± 0.92			

The standard error for comparing cultivars at a given sowing date is ± 2.9 and for comparing sowing dates in a cultivar is ± 4.0.

Table 6. Dry weight at 80 days after sowing of 4 pigeonpea cultivars sown at monthly intervals.

Sowing date	Shoot dry weight (g/m^2)				Mean
	Cultivar				
	UPAS-120	T-21	C-11	NP(WR)-15	
April	168.8	239.8	315.4	200.7	231.2
May	178.1	279.7	252.6	282.2	248.2
June	23.4	111.0	119.8	83.1	84.3
July	27.8	80.1	42.6	134.7	71.3
September	21.9	31.1	21.4	34.8	27.3
October	40.1	57.1	61.5	62.2	55.3
November	11.6	18.3	16.6	21.8	17.1
December	19.8	22.8	24.8	28.4	24.0
January	36.0	48.9	61.1	62.8	52.2
February	36.0	46.1	52.1	56.9	48.0
SE					±13.7
Mean	56.4	93.5	96.9	96.8	
SE		± 4.5			

The standard error for comparing cultivars at a given sowing date is ±14.3 and for comparing sowing dates in a cultivar is ±18.5.

Table 7. Mean plant height, branch number per plant and LAI at 50 days after sowing of 4 pigeonpea cultivars planted at monthly intervals.

Sowing date	Plant height(cm)	Branches per plant	LAI
April	64	3.6	0.74
May	67	3.1	0.74
June	61	2.3	0.71
July	49	2.1	0.37
September	33	0.3	0.14
October	33	2.7	0.14
November	18	0	0.14
December	19	0	0.06
January	29	1.4	0.17
February	33	0.3	0.12
SE	± 3.5	±0.6	±0.08

There were clear differences between the cultivars in their performance, as indicated by the dry weight data. Taking the means for all planting dates, cv. UPAS-120 grew significantly less than the other cultivars, and this difference was apparent both 50 and 80 days after sowing (Tables 5 and 6). In the 50 days samples, cv. NP(WR)-15 had also, on average, grown significantly less than cvs. T-21 and C-11.

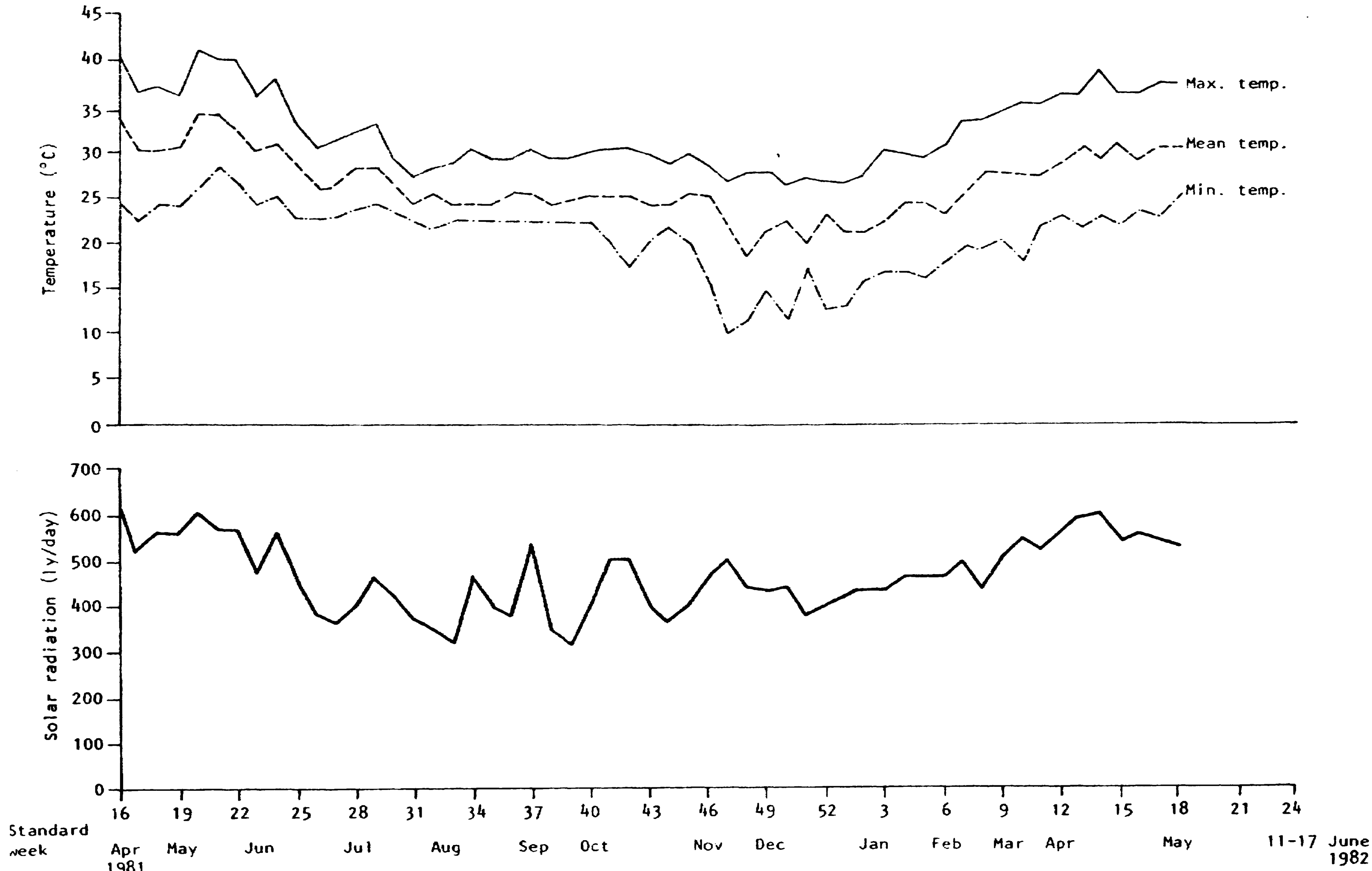
The differences between cv. NP(WR)-15 and cvs. T-21 and C-11 were most pronounced in the earlier sowings, when more growth took place; but in almost all sowings cv. UPAS-120 grew less than the other cultivars (Tables 5 and 6). Although in the 80 days sampling, comparisons of the cultivars are complicated by the fact that some were in the pod-filling phase and some were not, at 50 days the differences were almost entirely due to vegetative growth. It is possible that in the case of cv. NP(WR)-15 the inferior growth to cvs. T-21 and C-11 in the earlier plantings reflects a cultivar difference in response to temperature; but the consistently poorer performance of cv. UPAS-120 requires a different kind of explanation.

One reason could be in terms of its smaller seeds. Its 100-seed weight in the July planting was only 5.4 g., compared with 6.9 g. in cv. T-21, 9.8 g. in cv. C-11 and 7.2 g. in cv. NP(WR)-15 (Table 9). We have found that smaller seeded cultivars generally give rise to smaller seedlings, and even at 56 days after sowing, seed weight and shoot weight show a significant positive correlation (PPR 1975-76, Section III.1). However, the difference between cv. UPAS-120 and the other cultivars seems too great to be explicable in terms of seed size alone; it possibly reflects an inherently lower photosynthetic or metabolic efficiency.

Effects of climatic factors:

The weekly averages for maximum, mean and minimum temperatures and solar radiation throughout the experimental period are shown in Fig. 3. The mean temperatures shown in this figure were based on daily means obtained by averaging the temperature at 1 h. intervals throughout the day and night. Much of the time these calculated means were roughly intermediate between the maximum and minimum temperatures, but in some periods, notably from July to September, were closer to the minimum, and in others, e.g. during December, were closer to the maximum. From July to January solar radiation fluctuated considerably but showed no declining trend as the daylengths become shorter, because the clearer skies in the winter season roughly offset the effects of shorter daylengths.

The mean values of various climatic factors over the first 50 days after each sowing were calculated, and are shown together with the mean shoot dry weights at 50 days after sowing in Fig. 4.



Temperature (°C)
Max. temp.
Mean temp.
Min. temp.
Solar radiation (ly/day)
Standard week
Apr 1981
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
11-17 June 1982

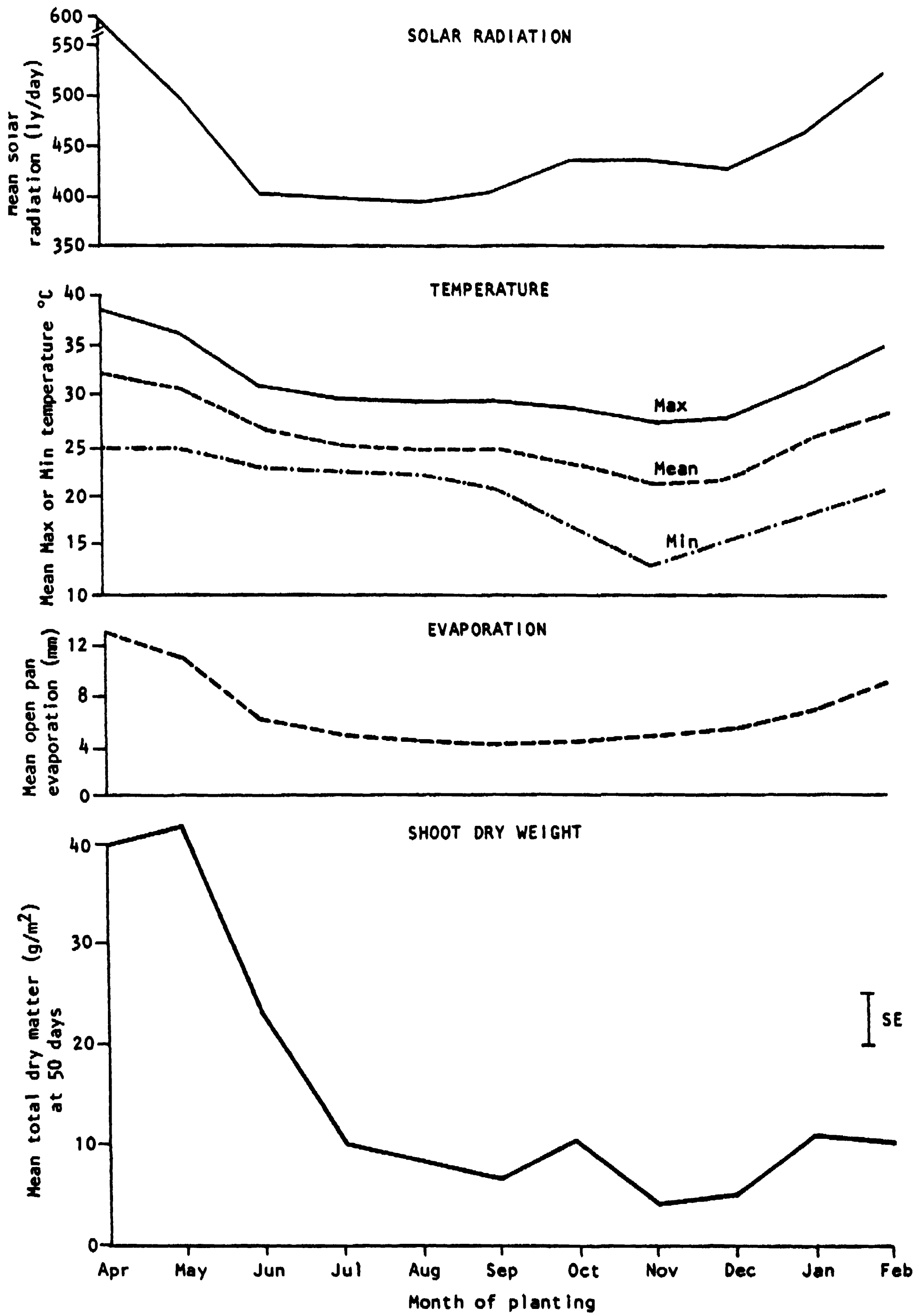


Figure 4. Mean total shoot dry weight of 4 pigeonpea cultivars 50 days after sowing in different months, and the mean radiation, evaporation and maximum and minimum temperatures prevailing during their 50-day growth period.

The greater growth in the April and May plantings was associated both with higher temperature and with higher solar radiation. However, from June to September, the mean solar radiation was similar. Smaller amount of dry matter in the later plantings may therefore primarily be due to the lower temperatures. More dry matter was produced with the October planting; although temperatures were lower than for the September planting, solar radiation was more, which may help to account for this. But in spite of higher radiation, growth was at a minimum in the November and December plantings, probably because of the cool weather.

In the January and February sowings, maximum temperatures were comparable to those for May and June sowings, and solar radiation was also high. However, growth was relatively poor perhaps because of the relatively low minimum temperatures.

The average dry matter production by the 4 cutivars over the first 50 days after the different sowings is plotted against the average maximum, mean and minimum temperatures over the same 50 day period in Fig. 5. In no case was ther a clear linear relationship. Perhaps the most interesting feature of this figures is the relationship of average dry matter production with minimum temperature, which suggests that there was a kind of discontinuous relationship with relatively little growth below a minimum temperature of about 22 °C., and much more growth above this temperature.

Not surprisingly, temperature was positively correlated with growth when all plantings were taken into account and there was also a weak positive correlation with solar radiation (Table 8). When the data for April, May, January and February plantings were omitted, solar radiation was no longer positively associated with growth (see Fig. 4), but there was still a strong positive correlation with temperature (Table 8).

In summary, these data indicate that in this experiment the growth of pigeonpeas was strongly influenced by temperature, with relatively poor growth when minimum temperatures are below about 22 °C. Growth was best at the highest temperatures, although the somewhat lower growth in the April than the May planting in some cultivars (Table 5), suggests that maximum temperatures above about 36 °C., may be superoptimal (see temperature data in Fig. 4).

Effects on yield components:

With sowings from April to October, there was little change in the number of seeds per pod, but there were noticeably fewer in the November planting (Table 9). This is not readily explicable in terms of low temperatures during the early reproductive phase, since these plants were flowering in early February (Table 4), when temperatures were higher than in December and January. One possible explanation might be in terms of higher insect attack on the pods of these November sown plants.

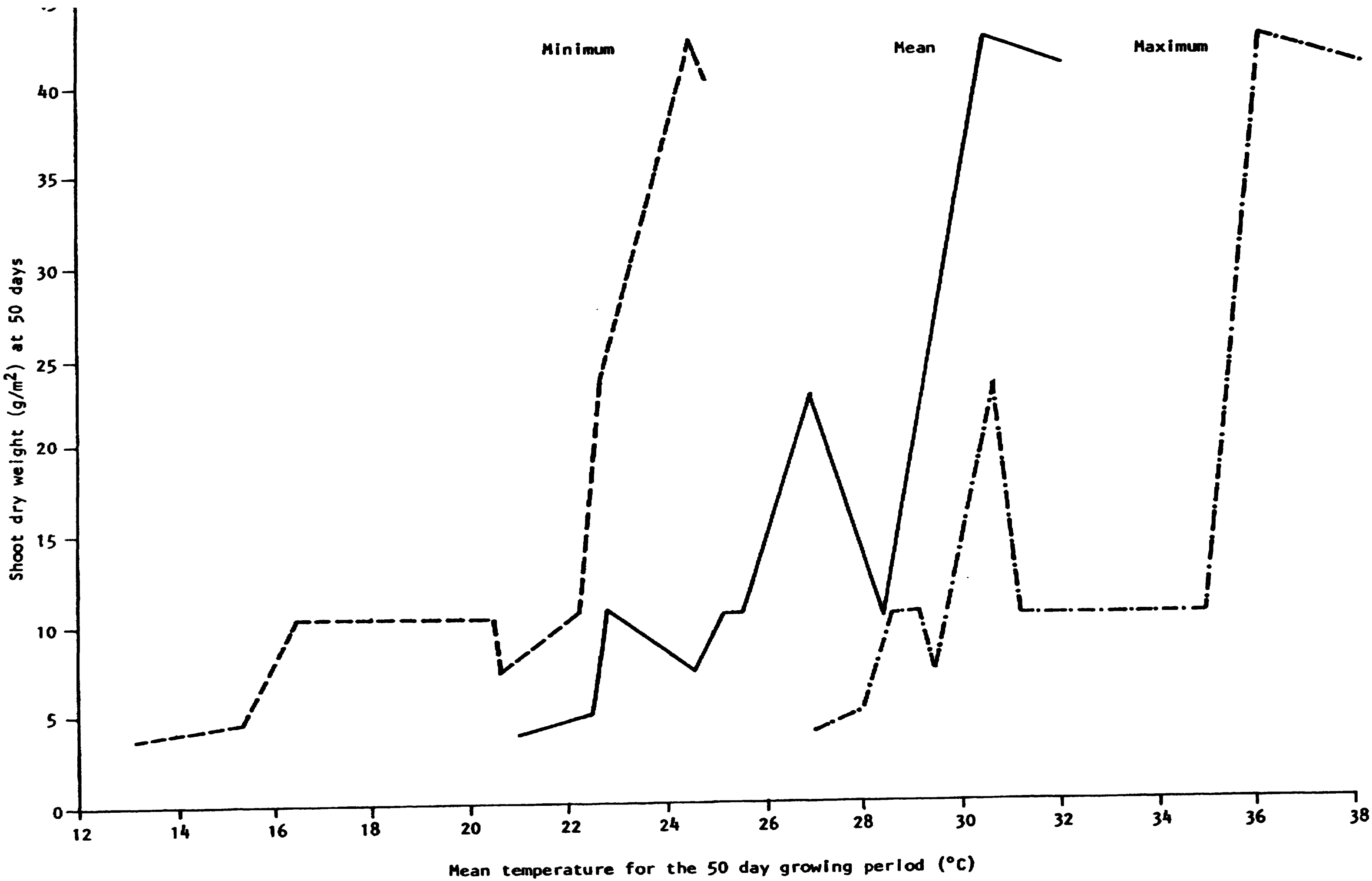


Figure 5. Relation between shoot dry weight at 50 days and the mean maximum, mean and minimum temperatures for the 50 day

Table 8. Simple correlation coefficients for toal dry weights at 50 days with average mean, maximum and minimum temperatures over the 50-day growing period.

Variable	Cultivar			
	UPAS-120	T-21	C-11	NP(WR)-15
All sowings				
Mean temperature	0.80**	0.87**	0.86**	0.87**
Max. temperature	0.78**	0.82**	0.84**	0.80**
Min. temperature	0.70*	0.79**	0.75*	0.84**
Solar radiation	0.57	0.60	0.67*	0.52
June-December sowings only				
Mean temperature	0.83*	0.81	0.78	0.92**
Max. temperature	0.91*	0.83*	0.83*	0.93**
Min. temperature	0.72	0.66	0.61	0.83*
Solar radiation	-0.38	-0.40	-0.33	-0.59

Table 9. Effect of planting date on seed number per pod and 100-seed weights of 4 pigeonpea cultivars.

Sowing date	Seed per pod				100-seed weight (g)			
	UPAS-120	T-21	C-11	NP(WR)-15	UPAS-120	T-21	C-11	NP(WR)-15
April	2.4	2.2	2.1	1.9	5.0	6.3	8.3	6.2
May	2.5	2.3	2.5	1.8	5.9	6.7	8.8	7.1
June	2.4	2.6	2.4	1.7	5.9	7.1	9.6	7.1
July	2.6	2.4	2.3	1.9	5.4	6.9	9.8	7.2
August	2.9	2.5	2.0	2.1	5.6	7.0	9.5	6.7
September	2.1	2.3	2.4	1.9	6.6	7.0	8.6	6.2
October	2.4	2.5	2.4	1.6	6.4	6.8	8.7	6.0
November	1.8	1.8	1.8	-	5.6	7.0	6.3	-
December	1.5	2.2	1.9	-	5.5	6.1	8.5	-
January	2.0	2.0	1.9	-	5.5	6.1	7.4	-

In all cultivars the 100-seed weights in the April sowing were lower than in the subsequent sowings. In cv. C-11 seed weights were highest in the June-August sowings (Table 9), but in otherwise the fluctuations showed no clear pattern.

III. THE YIELD POTENTIAL OF MEDIUM DURATION PIGEONPEAS

Medium duration pigeonpea cultivars are well adapted to cropping systems in peninsular India. They are usually planted around the beginning of the monsoon season, in June or July, and harvested around December. In farmers' fields they are often grown as an intercrop.

The yields of even the best available cultivars are relatively low. Tables 10, 11, 12 and 13 show the yields of such cultivars grown at ICRISAT Center in the normal season as a pure crop in Pulse Physiology, Pigeonpea Breeding, Pulse Entomology and Farming Systems trials. Even under the favourable conditions prevailing in these experiments, including adequate population densities and insecticide sprays, the yields hardly ever exceeded 2000 kg/ha; the overall means were 1450 kg/ha on Vertisol and 1209 kg/ha on Alfisol. Yields of intercropped pigeonpeas are even lower.

In pure stands it has not proved possible to obtain more than a slight increase in yield by increasing the population density over that usually adopted, of around 44000 plants/ha. Owing to the plasticity of plants, there is a very broad yield plateau (PPR 1979-80, Section V).

Alfisols have a lower water-holding capacity than Vertisols. In fact that yields on Alfisols are generally lower than on Vertisols (Tables 10, 11 and 13) suggests that one factor limiting yield may be water stress. It is also possible that yield is limited by inadequate nitrogen fixation, macronutrient or micronutrient deficiencies. In order to assess the yield potential of medium duration pigeonpeas under conditions in which none of these factors should be limiting, we carried out trials at ICRISAT Center on both soil types in which the plants were provided with ample supplies of nutrients and regular irrigation.

Materials and methods

The trials were laid with unreplicated large plots, using 5 medium duration genotypes were tested: ICP-1-6, ICPH-6, ICPL-270, C-11, and BDN-1. These were planted in two soil types, Vertisol field BP-14A and Alfisol field RP-4B on 19th and 20th June respectively. Both fields received a blanket application of 40 kg N, 70 kg P_2O_5 and 50 kg $ZnSO_4$ per ha. Placement of 3% furadan (@ 40 kg/ha) was also carried out prior to sowing. The seeds were treated with Rhizobium strain IHP-100. The plot size for each cultivar was 0.05 ha in each soil.

Table 10. Yields of medium duration pigeonpea cultivars grown in the normal season in Pulse Physiology trials on Vertisols and Alfisols at ICRISAT Center.

Vertisol			Alfisol		
Cultivar	Yield (kg/ha)	Reference (PPR)	Cultivar	Yield (kg/ha)	Reference (PPR)
ICP-1	1432	1975/76 Table 13	ICP-1	1337	1975/76 Table 37
ST-1	1508	1975/76 Table 32	ST-1	1336	1975/76 Table 33
ICP-1	1007	1976/77 Table 7	ICP-1	696	1976/77 Table 7
ICP-1	1876	1977/78 Table 23	ICP-1	886	1977/78 Table 25
BDN-1	1838	1977/78 Table 30	BDN-1	1564	1977/78 Table 26
BDN-1	1607	1978/79 Table 26	BDN-1	1130	1978/79 Table 27
BDN-1	1656	1978/79 Table 28	BDN-1	1118	1978/79 Table 28
C-11	1702	1978/79 Table 28	C-11	1314	1978/79 Table 28
ICP-1	1626	1978/79 Table 34	ICP-1	1197	1978/79 Table 34
BDN-1	1136	1979/80 Table 13	BDN-1	1264	1979/80 Table 14
C-11	1329	1979/80 Table 18	C-11	1503	1979/80 Table 18
BDN-1	1471	1979/80 Table 18	BDN-1	1351	1979/80 Table 18
C-11	1439	1980/81 Table 4	C-11	1123	1980/81 Table 4
BDN-1	1405	1980/81 Table 9	BDN-1	946	1980/81 Table 9
MEAN	1502		MEAN	1197	

Table 11. Yields of medium duration pigeonpeas grown as a sole crop in the normal season in ICRISAT Pigeonpea Breeders' trials. References are to Pigeonpea Breeding Reports (PBR). ACT-2 means refer to the mean yields in All India Coordinated Pulse Improvement trials of medium duration cultivars.

Vertisol			Alfisol		
Cultivar	Yield (kg/ha)	Reference (PBR)	Cultivar	Yield (kg/ha)	Reference (PBR)
ACT-2 Mean	1758	1974/75 Table 53	ACT-2 Mean	1208	1974/75 Table 54
C-11	1138	"	C-11	1474	"
ST-1	2016	"	ST-1	1051	"
ACT-2 Mean	1277	1975/76 Table 65			
C-11	1929	"			
ST-1	1365	"			
ICP-1	1134	"			
BDN-1	1466	"			
C-11	1721	1976/77 Table 105			
ST-1	1333	"			
ICP-1	1504	"			
ACT-2 Mean	1150	1977/78 Table 2.36	ACT-2 Mean	932	1977/78 Table 2.35
C-11	1048	"	C-11	926	"
BDN-1	1222	"	BDN-1	930	"
ACT-2 Mean	1171	1978/79 Table 2.30			
C-11	1448	"			
ICP-1	1295	"			
BDN-1	1190	"			
MEAN of ACT-2 trials	1339		MEAN of ACT-2 trials	1070	

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Table 12. Yields of medium duration pigeonpeas in ICRISAT Pulse Entomology trials under insecticide sprayed conditions on Vertisols. The highest yielding cultivar in each trial is indicated by an asterisk.

Cultivar	Yield (kg/ha)	Reference (Pulse Entomology Report)
ICP-1	1312	1978/79 Table 19
C-11	1877	"
6496-EL-EB*	1901	"
BDN-1*	1434	1979/80 Table 15
C-11	1148	"
BDN-1	1471	1980/81 Table 18
C-11*	1713	"
Mean	1551	

Table 13. Yields of medium duration pigeonpeas grown as a sole crop during the normal season in ICRISAT Farming Systems trials. References are to Farming Systems Annual Reports (FSR) or reports on Cropping Systems Research (CSR).

Vertisol			Alfisol		
Cultivar	Yield (kg/ha)	Reference	Cultivar	Yield (kg/ha)	Reference
HY-3A	1890	FSR 1974/75 Table 7	ICP-1	1710	FSR 1974/75 Table 6
ST-1	1670	FSR 1975/76 Table 25	ST-1	1070	FSR 1975/76 Table 25
ICP-1	1250	CSR 1976/77 Table 6	ICP-1	800	CSR 1976/77 Table 6
ICP-1	1645	CSR 1979/80 Table 1	ICP-1	1900	CSR 1979/80 Table 1
ICP-1	1330	CSR 1979/80 Table 5	ICP-1	1222	CSR 1979/80 Table 5
C-11	1270	"	C-11	1454	"
Mean	1509		Mean	1359	

Planting was done on 75 cm ridges at a spacing of 75 x 10 cms. This gave a population of 133,300 plants/ha. The final population at harvest was over 90% of this in Vertisol and between 70-88% in Alfisol (Table 14).

The crop received three irrigations after the commencement of flowering, on 2.11.81, 17.11.81 and 3.12.81 on Vertisol and on 22.10.81, 6.11.81 and 21.11.81 on Alfisol. Two sprays of micronutrients were given, one during the vegetative stage (24.7.81) and another at flowering stage (13.10.81 on Vertisol; 1.10.81 on Alfisol) to guard against micronutrient deficiency. At the time of harvest, each block was divided into 7 and 8 sub-blocks of 58 and 53 m^2 area in Vertisol and Alfisol fields respectively to get an idea of uniformity of the crop. Subsamples of 10 plants were taken from each sub-block for the estimation of total dry weight and components of yield. The Harvest Index was calculated from these subsample data, and then used to calculate the total dry weight of the crop from the plot yield data. The pod number per plant was also calculated from plot yield data, using data on 100-seed weight and seed number per pod from the subsamples.

On both soils with cvs. BDN-1 and ICP-1-6 one sub-block was ratooned and another sub-block harvested by pod-picking at the time of maturity of the first crop during the first week of January, and the plants were left to produce a second flush of pods. These plants were irrigated on 25.1.82, 15.2.82 and 22.2.82 on Vertisol and on 27.12.81, 14.1.82 and 23.1.82 on Alfisol. On both soils the ratooned plants of cv. BDN-1 matured in mid-March, about 8 days later than the non-ratooned plants. The non-ratooned plants of cv. ICP-1-6 matured in mid-March and the ratooned plants in mid-April

Results and discussion

First harvest:

Most of the cultivars flowered and matured a few days earlier on Alfisol than Vertisol (Table 15). In unirrigated trials in previous years the differences between the two soil types are generally more pronounced, with maturity occurring up to 16 days sooner on Alfisol than Vertisol (Table 16). These data suggest that the greater water stress on Alfisol accelerated both flowering and maturation. In this year's trials the duration of both cvs. C-11 and BDN-1 was extended by 2-3 weeks compared with previous years and flowering also took place several weeks later than in some previous years (compare Tables 15 and 16). Since this year's trial was irrigated and previous trials were not, these results again point to the conclusion that flowering and maturation are accelerated by water stress; or, putting it in a different way, that an adequate water

Table 14. Plant population at harvest as percentage of the expected population, and percentage of plants which were dead at the time of harvest.

Cultivar	Percentage of expected population		Percentage of dead plants	
	Vertisol	Alfisol	Vertisol	Alfisol
ICP-1-6	95.6	70.0	1.2	5.6
ICPL-270	95.1	83.9	0.9	11.6
ICPH-6	90.5	83.8	1.2	17.6
C-11	92.6	85.4	1.1	11.2
BDN-1	96.4	88.0	0.9	5.5

Table 15. Growth duration, mean crop growth rate and Grain productivityof medium duration cultivars grown in the kharif season under high input conditions in Vertisol and Alfisol at ICRISAT Center.

Cultivar	Days to 50% flowering		Days to maturity		Mean crop growth rate kg/ha/day		Grain productivity kg/ha/day	
	Vertisol	Alfisol	Vertisol	Alfisol	Vertisol	Alfisol	Vertisol	Alfisol
ICP-1-6	138	135	200	193	51.1	53.9	11.53	6.14
ICPL-270	133	132	192	187	39.9	40.1	10.24	7.94
ICPH-6	132	132	192	191	45.5	35.8	10.49	6.87
C-11	132	130	187	187	50.7	40.5	10.44	7.45
BDN-1	127	124	184	181	38.0	46.9	10.31	10.25

Table 16. Days to flowering and maturity of cvs. ICP-1, BDN-1 and C-11 in Pulse Physiology trials during the normal season at ICRISAT Center.

Vertisol				Alfisol			
Cultivar	Days to flowering	Days to maturity	Reference (PPR)	Cultivar	Days to flowering	Days to maturity	Reference (PPR)
ICP-1	120	174	1978/79 P. 32	ICP-1	110	163	1978/79 P. 32
ICP-1	124	176	1978/79 P. 54	ICP-1	107	160	1978/79 P. 54
Mean	122	175			109	162	
BDN-1	116	163	1978/79 P. 51	BDN-1	101	152	1978/79 P. 51
BDN-1	107	166	1979/80 P 26	BDN-1	85	161	1979/80 P. 26
BDN-1	98	165	1979/80 P. 38	BDN-1	83	160	1979/80 P. 38
BDN-1	115	162	1980/81 Table 7	BDN-1	115	154	1980/81 Table 7
Mean	109	164			96	157	
C-11	119	165	1978/79 P. 52				
C-11	123	167	1979/80 Table 4				
C-11	108	166	1979/80 P. 26				
C-11	96	165	1979/80 P. 38	C-11	86	155	1979/80 P. 38
C-11	131	162	1980/81 On file				
Mean	115	168					

able 17. Yield and yield components of medium duration cultivars grown with irrigat and nutrient inputs in the normal season at ICRISAT Center on Vertisol (V) Alfisol (A). Values are shown with standard errors.

ariable	Soil	Cultivar					Me
		BDN-1	C-11	ICP-1-6	ICPH-6	ICPL-270	
Yield (kg/ha)	V	1900 ± 43	1950 ± 37	2300 ± 20	2010 ± 44	1970 ± 29	20[illegible]
	A	1850 ± 53	1390 ± 104	1180 ± 43	1310 ± 165	1480 ± 61	14[illegible]
Yield/plant (g)	V	15 ± 0.4	18 ± 0.4	18 ± 0.2	17 ± 0.3	15 ± 0.3	[illegible]
	A	16 ± 0.6	13 ± 1.0	13 ± 0.8	12 ± 1.7	13 ± 0.4	[illegible]
Total dry weight (kg/ha)	V	7000 ± 154	9570 ± 353	10340 ± 460	8800 ± 287	7720 ± 272	86[illegible]
	A	8760 ± 639	7560 ± 479	11130 ± 1128	6900 ± 854	7750 ± 578	84[illegible]
Total dry weight/plant (g)	V	55 ± 1.2	89 ± 3.3	81 ± 3.6	41 ± 1.3	61 ± 2.1	[illegible]
	A	75 ± 5.4	70 ± 4.4	120 ± 12.2	62 ± 7.7	69 ± 5.1	[illegible]
Fallen leaves (kg/ha)	V	3230 ± 512	2720 ± 332	3150 ± 571	2910 ± 560	2240 ± 502	35[illegible]
	A	1940 ± 451	2100 ± 201	2570 ± 196	1870 ± 114	1830 ± 116	20[illegible]
Harvest Index (%)	V	27 ± 0.4	21 ± 0.6	22 ± 0.9	23 ± 1.1	26 ± 1.0	[illegible]
	A	21 ± 1.4	18 ± 0.8	11 ± 1.2	19 ± 0.9	20 ± 1.5	1[illegible]
Pod No./plant	V	50 ± 1.1	64 ± 2.5	64 ± 1.2	64 ± 1.6	48 ± 1.3	[illegible]
	A	60 ± 1.9	53 ± 3.9	66 ± 3.7	50 ± 6.3	47 ± 1.3	[illegible]
d No./pod	V	2.7 ± 0.05	2.4 ± 0.06	2.6 ± 0.04	3.0 ± 0.04	2.7 ± 0.05	2.[illegible]
	A	2.3 ± 0.09	2.6 ± 0.06	2.1 ± 0.05	2.7 ± 0.07	2.7 ± 0.07	2.[illegible]
100-seed weight (g)	V	11 ± 0.2	10 ± 0.2	11 ± 0.3	9 ± 0.1	12 ± 0.1	1[illegible]
	A	11 + 0.2	9 + 0.2	9 + 0.4	9 + 0.3	11 + 0.4	1[illegible]

supply prolongs both the vegetative and the reproductive phases. A similar effect would be expected in years in which the rainfall relatively high and the rainy season is unusually prolonged. This year was such a year (Fig. 1), and in cv. C-11 grown on a Vertisol without irrigation, the number of days to 50% flowering and to maturity (132 and 188 days respectively: see p. 60) was considerably greater than in previous years, and almost the same as in this irrigated trial.

The plant stands on Vertisol were excellent, with over 90% of the theoretical population alive at the time of harvest (Table 14). On Alfisol, however, stands were reduced in most cultivars mainly because of the wilt disease.

In most cultivars the yield was strikingly higher in Vertisol than Alfisol, with means of 2030 kg/ha and 1450 kg/ha respectively (Table 17). Only in cv. BDN-1 were the yields similar on both soils; this was the cultivar least affected by the wilt disease on Alfisol (Table 14). The cultivar which showed the greatest discrepancy between the two soils, ICP-1-6, with a yield of 2305 kg/ha on Vertisol and 1185 kg/ha on Alfisol, had the lowest plant stand on the latter, only 70% of the theoretical population (Table 14). However, not only were there fewer plants on Alfisol, but the yield per plant was lower (12.8 g compared with 18.1 g on Vertisol). Although the pod number per plant on both soils was almost the same (65.8 on Alfisol, 63.7 on Vertisol), on Alfisol there were fewer seeds per pod (2.11 as opposed to 2.60) and a lower 100-seed weight (9.3 g as opposed to 11.0 g).

Except for cv. BDN-1, the other cultivars like cv. ICP-1-6, yielded less on Alfisol than Vertisol both because of a lower plant population (Table 14) and a lower yield per plant (Table 17). The latter was due to a smaller number of pods per plant, a lower 100-seed weight, and also in the case of cvs. ICP-1-6 and ICPH-6 fewer seeds per pod (Table 17). In previous years in unirrigated trials there has been a tendency for plants grown on Alfisol to have fewer seeds per pod than on Vertisol, but 100-seed weight have tended to be higher on Alfisol (Table 18).

Although the total dry weight per hectare in the shoot system at the time of harvest was similar on both soil types, there was a much greater mass of fallen leaves beneath the plants on Vertisol than on Alfisol (Table 17), indicating that they had put on more vegetative growth throughout the growing season. The greater production of leaves and the higher yield of the plants on Vertisol, together with their somewhat later maturity, may indicate that in spite of the long rainy season and irrigation, the growth and yield of the plants on Alfisol was still limited by moisture stress, perhaps during the later part of the reproductive phase (the last irrigation was given on 21.11.81, over a month before maturity; on Vertisol the plants received their last irrigation somewhat later, on 3.12.81.

Table 18. Seeds per pod and 100-seed weight of medium duration pigeonpea cultivars grown in the normal season in Pulse Physiology trials on Vertisol and Alfisol at ICRISAT Center. References are given to previous pigeonpea physiology reports.

Vertisol				Alfisol			
Cultivar	Seeds/pod	100-seed weight (g)	Reference (PPR)	Cultivar	Seeds/pod	100-seed weight (g)	Reference(PPR)
ST-1	2.5	7.0	1975/76 Table 22	ST-1	2.6	7.0	1975/76 Table 22
ICP-1	2.9	8.7	1976/77 Table 8	ICP-1	2.9	8.7	1976/77 Table 8
ICP-1	2.5	8.2	1977/78 Table 23	ICP-1	2.5	8.8	1977/78 Table 25
C-11	3.2	9.3	1978/79 Table 29	C-11	2.9	9.4	1978/79 Table 29
BDN-1	3.1	7.9	1978/79 Table 29	BDN-1	2.7	9.6	1978/79 Table 29
ICP-1	3.1	8.4	1978/79 Table 34	ICP-1	2.8	8.8	1978/79 Table 34
BDN-1	2.7	9.2	1979/80 On file	BDN-1	2.9	10.1	1979/80 On file
BDN-1	2.7	10.1	1979/80 On file	BDN-1	2.6	10.5	1979/80 On file
C-11	2.9	9.6	1979/80 On file	C-11	2.7	11.0	1979/80 On file
C-11	2.7	9.2	1980/81 Table 4	C-11	2.7	9.2	1980/81 Table 4
BDN-1	2.8	9.3	1980/81 On file	BDN-1	2.4	9.6	1980/81 On file
Mean	2.8	8.8		**Mean**	2.7	9.3	

The nitrogen and phosphorus content of various plant parts in cvs. BDN-1 and C-11 at the time of the first harvest was generally similar on both soils (Table 19). The percentage of both N and P in stems and fallen leaves were considerably higher than those found in unirrigated pigeonpeas (cf. PPR 1975-76, Table 13; PPR 1976-77, Tables 10 and 11). The nitrogen content of fallen leaves is usually around 1.3 - 1.5%, but in this irrigated trial was 2.2 - 2.7%. In cv. BDN-1 on Vertisol, for example, the nitrogen content was 2.4%, and the total quantity of fallen leaves was 3230 kg/ha (Table 19). This means that the amount of nitrogen returned to the soil in this form was 78 kg/ha, far more than we have ever found before.

Second harvest:

Second harvest yields were generally higher on Alfisols than Vertisols, in spite of the higher water-holding capacity of the latter. We think that the lower yields on Vertisol are mainly due to the cracking of the soil which occurs progressively in the post-rainy season (PPR 1980-81, Section VIII; this report, Section X). If this is so, then with irrigation the cracking in Vertisol should be suppressed, and the differences between the two soil type reduced.

This indeed appears to be the case. In this experiment, subplots of two cultivars, BDN-1 and ICP-1-6, were harvested by ratooning or by pod-picking at the time of the first harvest (in early January) and the plants were left in the field to produce a second flush of pods. They were irrigated during the period this second flush was developing. In cv. BDN-1 the yield on Vertisol of 744 kg/ha (Table 20) was far higher than any second harvest yield previously recorded on this soil type, which with this cultivar have ranged from 50 - 330 kg/ha. These figures refer to non-ratooned plants, with ratooning the yields were lower, as this year's data also show (Table 20). The yield on Alfisol of this cultivar was lower than on Vertisol, probably as a consequence of greater water stress (the plants on Alfisol were not irrigated after 23.1.82, whereas on Vertisol the last irrigation was given a month later, on 22.2.82).

The second flush of pods matured somewhat later in cv. ICP-1-6 and this may help to account for the fact that the yield on Vertisol was lower than in the case of BDN-1, particularly in the case of ratooned plants (Table 20). However on Alfisol the yield of the non-ratooned plants was quite high, in spite of the fact that only 65% of the initial plant population had survived, compared with over 90% on Vertisol. The better performance of cv. ICP-1-6 on Alfisol than Vertisol, the reverse of what was found in cv. BDN-1 may be due to the fact that the vegetative growth of the plants of cv. ICP-1-6 on Alfisol was much greater than on Vertisol (see data for dry weight per plant in Table 17), and on Alfisol more regrowth occurred after the first harvest in this cultivar than in cv. BDN-1.

Table 19. Nitrogen and phosphorus content of various plant parts at the time of first harvest of cvs. BDN-1 and C-11, grown on Vertisol (V) and Alfisol (A) with irrigation and nutrient inputs.

Plant part	N %				P %			
	cv.BDN-1		cv.C-11		cv. BDN-1		cv. C-11	
	V	A	V	A	V	A	V	A
Attached leaves	4.0	3.9	4.1	4.1	0.34	0.23	0.27	0.24
Stems	0.9	1.1	0.9	0.7	0.18	0.23	0.17	0.14
Seeds	3.3	3.2	3.8	3.4	0.45	0.36	0.47	0.35
Fallen leaves	2.4	2.2	2.7	2.7	0.20	0.15	0.20	0.21

Table 20. Second harvest yields and yield components of ratooned and non-ratooned plants of cvs. BDN-1 and ICP-1-6 on Vertisol (V) and Alfisol (A).

Cultivar	Treatment	Yield (kg/ha)		Yield per plant (g)		Seeds per pod		100-seed weight (g)	
		V	A	V	A	V	A	V	A
BDN-1	Non-ratooned	744	454	5.9	4.3	2.0	1.6	9.0	7.3
	Ratooned	481	263	4.0	2.2	2.0	1.4	9.2	7.3
ICP-1-6	Non-ratooned	459	583	3.3	6.8	1.4	1.8	8.0	8.3
	Ratooned	155	222	1.3	2.5	1.6	1.6	7.3	7.5

In the second flush in both cultivars the seed number per pod and 100-seed weights were lower than in the first flush: for example, in cv. BDN-1, on Vertisol there were 2.7 seeds per pod in the first flush, and 2.0 in the second, and the respective 100-seed weights were 10.8 g and 9.0 g. The differences were even greater in cv. ICP-1-6 (compare Tables 17 and 20). A similar reduction in both these components of yield in the second flush has also been observed in previous years (Table 21).

General discussion: Why are medium duration pigeonpeas low yielding?

Yields of extra-early pigeonpeas grown in the monsoon season in north India often exceed 3 tons/ha; for example this year in an ICRISAT trial at Hissar cv. ICPL-87 yielded 3420 kg/ha, maturing in 143 days (Table 23). At ICRISAT Center extra-early cultivars, maturing in about 100 days, grown at high population densities, have recently been found to give yields as high as 2700 kg/ha (data from 1982 trials, to be described in next year's Pigeonpea Physiology Report).

Late maturing pigeonpeas grown in Uttar Pradesh and Madhya Pradesh also give good yields. In Mainpuri District (U.P.), for example, the average yields in farmers' fields are as high as 3 tons/ha.

By contrast, medium duration pigeonpeas rarely yield more than 2 tons/ha even under favourable conditions on experiment stations. For example, in our Pulse Physiology trials from 1975 to 1981, the highest yield was 1876 kg/ha; the mean yields on Vertisol and Alfisol were 1502 kg/ha and 1197 kg/ha respectively. In some representative Farming Systems trials, yields ranged from 800-1890 kg/ha (Table 13). In Pigeonpea Breeders' trials the mean yields of medium duration cultivar trials (ACT-2) were 1339 kg/ha on Vertisol and 1070 kg/ha on Alfisol (Table 11). In the best year, 1974-75, the highest yielding cultivar gave 2,340 kg/ha. In Pulse Entomology trials, under insecticide sprayed conditions the best cultivars have yielded between 1430 and 1901 kg/ha (Table 12).

This year, like 1974-75, was an exceptionally good year for pigeonpea yields, and in our experiment in a Vertisol watershed, cv. C-11 yielded 1940 kg/ha in control plots (Table 30), and a record yield of 3220 kg/ha was obtained in one trial by the Pulse Entomologists, but this involved harvesting a June planted-early cultivar in February, so probably represents the total of first and second flush yields.

In the present experiment, in which irrigation and nutrient supplies were given in an attempt to optimize growth and yield, the highest yield was only 2305 kg/ha (Table 17). This suggests that yields are not being greatly limited by these factors. Taken together with the data summarized above, and also taking into account the results of All India Coordinated

Trials in the Central and Peninsular Zones, the results suggest that medium duration pigeonpeas have a low yield potential, which very rarely exceeds 2.5 tons/ha; whereas both early and late pigeonpeas quite often give yields of 3.5 tons or more. What could be the reasons for this?

The most likely explanation seems to be in terms of temperature. Early pigeonpeas sown in June or July mature before the cool winter weather of November-February. Late pigeonpeas in north India mature after this season, when the temperatures are rising. But medium duration cultivars go through their reproductive phase during this cool season (Fig. 6).

The growth of pigeonpeas is markedly enhanced at higher temperatures, (see Section II). Other tropical crops such as sorghum and millet are known to show a linear response to temperature in a range above a critical 'base temperature' of about 10-12 °C. At or below this temperature developmental processes become very slow. Pigeonpea may have a similar temperature response. Indeed, observations on the rate of leaf initiation in controlled environments, made by Dr. M. McPherson in Palmerston North, New Zealand, indicate a 'base temperature' for this process of around 16 °C. During the cool winter season when night temperatures are often below 10 °C, developmental processes such as pod setting may be inhibited, with a consequent reduction of yield.

The idea that the relatively low yield of medium duration pigeonpeas is mainly due to cool temperatures rather than any inherent physiological deficiency compared with early and late pigeonpeas is supported by the results of trials carried out in the rabi season, with sowings from September to November. In our Pulse Physiology trials from 1975 to 1981 under these conditions, the highest yield obtained from an early cultivar has been 1080 kg/ha, compared with 1710 kg/ha from a medium cultivar and 1280 kg/ha from a late cultivar (PPR 1976-77, Table 61). In other years also, medium cultivars have generally outyielded both early and late cultivars.

A hint that cool temperatures may be limiting the development of reproductive structures is provided by data on seed number per pod and 100-seed weight of the some cultivars grown in the normal and the rabi seasons. In the rabi crop the temperatures during the flowering period (around January) are lower than in the normal crop (October-November for medium cultivars). Both seed number per pod and especially 100-seed weight tend to be lower in the rabi crops (Table 22). A similar pattern emerges, though with more striking differences in seed number per pod, when first and second harvests from the same plants are compared (Table 21); in this case also the second flush of flowering takes place in the cool weather around January.

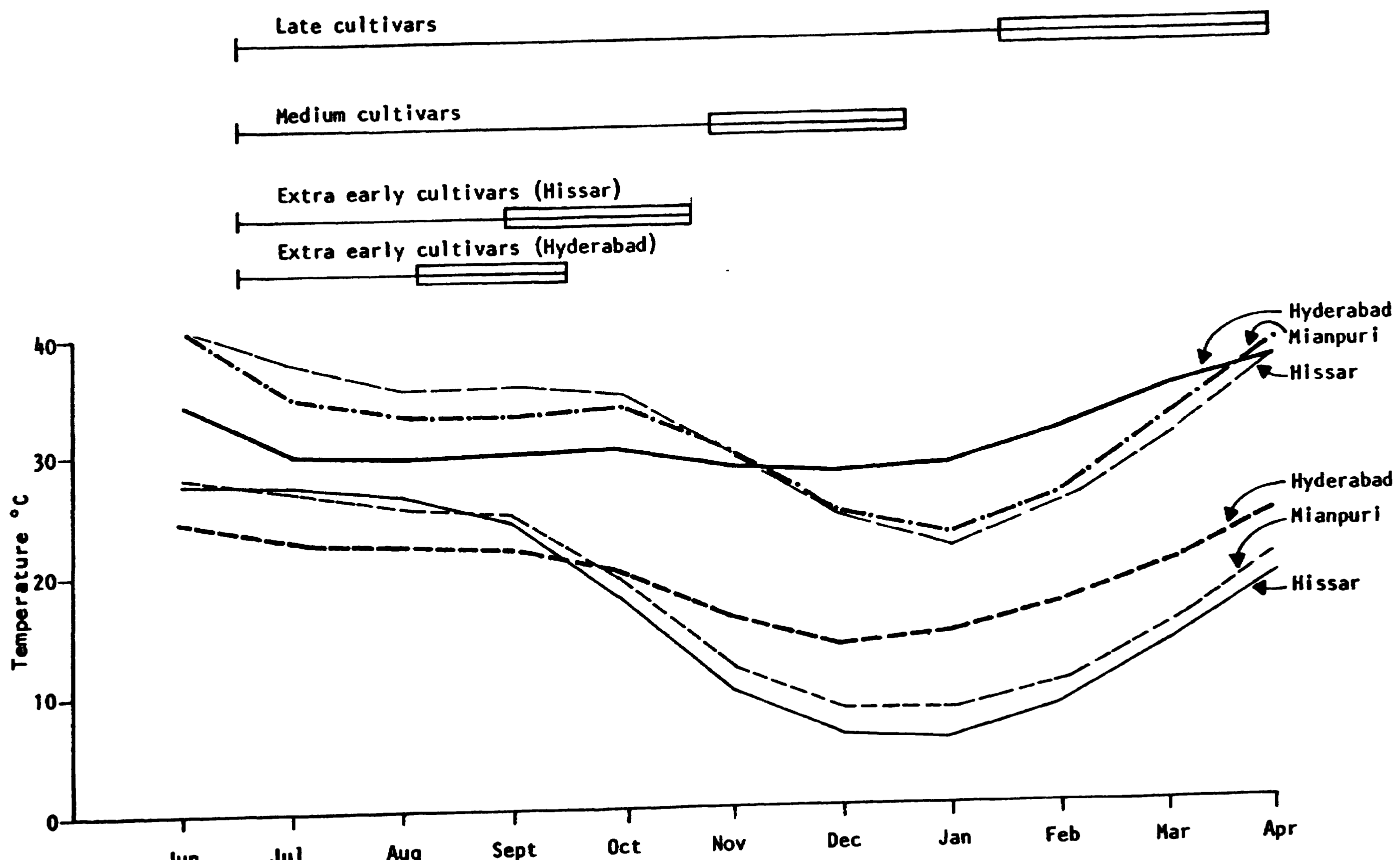


Figure 6. Mean monthly Maximum and Minimum Temperatures at Hyderabad, Mainpuri, and Hissar.

Table 21. Seed number per pod and 100-seed weight in first and second harvests of medium duration pigeonpeas in trials at ICRISAT Center on Vertisol (V) and Alfisol (A). Data are shown for non-ratooned plants grown without irrigation.

Cultivar	Soil	Seeds per pod		100-seed wt.(g)		Year
		First	Second	First	Second	
BDN-1	V	2.9	1.9	9.8	7.7	1977/78
"	A	2.6	2.4	9.0	8.6	"
BDN-1	V	3.1	1.8	8.2	8.2	1978/79
"	A	2.3	1.9	9.8	7.6	"
BDN-1	V	2.7	1.9	9.2	8.7	1979/80
"	A	2.9	1.9	10.1	8.8	"
C-11	V	2.8	2.0	9.5	9.6	"
Mean		2.8	2.0	9.4	8.4	

Table 22. Seed number per pod and 100-seed weight of pigeonpea grown in the kharif and rabi seasons at ICRISAT Center on Vertisol.

Cultivar	Seeds per pod		100-seed weight (g)		Reference (PPR)
	Kharif	Rabi	Kharif	Rabi	
ST-1	2.5	2.6	7.0	5.6	1975/76 Tables 22, 39
ICP-1	2.9	2.9	8.7	6.8	1976/77 Tables 8, 63
ICP-1	2.5	2.6	8.2	6.5	1977/78 Tables 20, 63, 64
BDN-1	2.9	2.1	9.8	7.5	"
ICP-1	3.0	2.7	8.4	5.3	1978/79 Tables 10, 42
BDN-1	3.1	2.6	8.2	5.7	"
BDN-1	2.7	1.8	10.1	8.5	1979/80 Tables 7, 22
C-11	2.6	2.6	9.7	6.6	"
C-11	2.7	2.0	9.2	8.4	1980/81 Tables 4, 26, 27
Mean	2.8	2.4	8.8	6.8	

However, the most important component of yield is pod number per plant, and the lower yields of pigeonpeas undergoing their reproductive phase during the cool season may primarily be due to a limitation on pod setting. Further evidence that this may be the case is provided by observations on long-duration pigeonpeas grown in North India (e.g. at Gwalior). Although flowering may begin in November or December, pod-set does not effectively take place until the weather begin to warm up, in February and March. This strongly suggests that the cold weather is inhibiting pod-set, which cannot begin until the temperature rises above a certain minimum. Comparable observations have been made on chickpeas at Hissar (CPR 1979-80, Section IX).

This hypothesis that the relatively low yield potential of medium duration pigeonpeas is a consequence of the fact that they undergo their reproductive phase in cool weather can be tested in at least two ways. One is to plant them in the normal season at locations in which the weather is warmer during the winter season, for example in southern Tamil Nadu or Kerala. Another is to warm them up during their reproductive phase during day time and/or night time. We are at present attempting to develop methods for doing this with field-grown plants.

IV. THE YIELD OF EXTRA-EARLY PIGEONPEAS AT HISSAR

Yields of well over 2 tons/ha can be obtained from extra-early cultivars grown in the monsoon season in north India. In this trial, carried out at Hissar by Dr. S.C. Gupta, of ICRISAT Pigeonpea Breeding Sub-program, the yield potential of some promising extra-early cultivars was assessed under irrigated conditions.

Materials and methods

Six extra-early cultivars were used: UPAS-120, ICPL-81, ICPL-87, ICPL-1, ICPL-267 and ICPL-179, of which 3 were determinate in habit (DT) and 3 indeterminate (NDT). Fields prior to planting received a basal dressing of single superphosphate equivalent to 20 kg/ha P_2O_5. Sowing was carried out on 23.6.81 with *Rhizobium* inoculated seeds, at a spacing of 30 x 10 cms with the rows running along the sides of 60 cms ridges. The final plant population at harvest was approximately 200,000 plants/ha.

Results and discussion

Although the duration of growth was considerably less than that of medium duration cultivars at Hyderabad, the yield levels were much higher (Table 23), with 3400 kg/ha from the best cultivar, ICPL-87 (derived from a cross between T-21 and JA-277). The overall crop growth rates and per day grain production were much higher than those of medium duration cultivars grown under favourable conditions at Hyderabad (compare Tables 15 and 23); the mean crop growth rates were 74 kg/ha/day at Hissar and 45 kg/ha/day on Vertisol in Hyderabad.

It seems unlikely that these extra-early cultivars are better *per se*, since when grown in the cool rabi season at Hyderabad their crop growth rates are low; for example in 1980-81, cv. UPAS-120 had a crop growth rate of only 12 kg/ha/day, compared with 20 kg/ha/day in ICP-1, (PPR 1980-81, Table 34). The most likely explanation for the high growth rates and yield levels of these cultivars at Hissar seems to be in terms of temperature; both maximum and minimum temperatures are 4-6° C higher than at Hyderabad from June to September (Fig. 6).

Table 23. Crop growth duration, mean crop growth rate, total drymatter and yield of extra-early cultivars grown under high input conditions at Hissar.

Cultivar	Habit	Crop growth duration (days)	Mean crop growth rate kg/ha/day	Total dry matter kg/ha	Grain productivity kg/ha/day	Grain yield kg/ha
ICPL-81	NDT	115	72.7	8365	19.4	2231
ICPL-1	NDT	136	63.7	8658	19.6	2670
UPAS-120	NDT	150	79.2	11881	15.1	2267
ICPL-87	DT	143	81.7	11673	23.9	3419
ICPL-267	DT	98	-	-	20.9	2047
ICPL-179	DT	99	-	-	14.8	1468

NDT = Non determinate; DT = Determinate

V. THE YIELD OF RABI PIGEONPEAS GROWN WITH FREQUENT IRRIGATION:

In previous years we have shown that the yield can be increased by irrigation (PPR 1978/79, Table 55; PPR 1979/80, Table 28; PPR 1980/81, Table 24). Greater responses were obtained with two irrigations than one, and with three irrigations than two. This year we studied the effect of more frequent irrigations on both Vertisol and Alfisol, hoping to find out the yield potential under conditions in which water stress and nutrient supplies should not have been limiting growth.

Materials and methods

Vertisol:

On Vertisol, the trial was sown in field BP-14A. The land had been fallow during the monsoon season, and in June had received a basal dressing of DAP (N 40 kg/ha; P_2O_5 70 kg/ha) and $ZnSO_4$ (50 kg/ha). For plant protection carbofuran (3% furadan) was applied to the soil at the rate of 40 kg/ha prior to sowing. The seeds were inoculated with Rhizobium strain IHP-100. The trial was sown on 22.10.81 at a spacing of 37.5 x 8 cms, with the rows running along the sides of ridges 75 cms apart. Five cultivars were sown in unreplicated plots of 10 x 45 m. The dates of flowering and maturity were as below, with the number of days after sowing in parentheses.

Cultivar	50% flowering	Maturity
BDN-1	5.1.82 (75)	3.3.82 (132
C-11	20.T.82 (90)	5.3.82 (134
ICPH-6	20.1.82 (90)	15.3.82 (144
ICP-2223-1-E8	25.1.82 (95)	15.3.82 (144
ICP-1-6	25.1.82 (95)	15.3.82 (144

The trial was irrigated along the furrows 7 times, on 22.10.81, 2.11.81, 17.11.81, 2.12.81, 25.1.82, 15.2.82 and 22.2.82. The plants were sprayed with micronutrient solution on 15.12.81.

Harvesting was carried out a few days after maturity. Each plot was divided into 7 sub-plots (net plot size 53.75 m^2) at the time of harvest, and standard errors were calculated on the basis of the sub-plot data. Sub-samples of 20 plants were taken from each sub-plot for the measurement of yield components.

Alfisol:

This trial was planted in field RP-4B, which had been fertilized in June as described above for the Vertisol field, and left fallow thereafter. Sowing was carried out on 75 cms ridges without prior carbofuran application or seed inoculation. Cvs. BDN-1 and C-11 were sown on 5.11.81 at 37.5 x 10 cms. (plot sizes 100 m^2). The trial was unreplicated. Phenological data were as follows:

Cultivar	50% flowering	Maturity
BDN-1	23.1.82 (80)	15.3.82 (131)
C-11	20.1.82 (77)	15.3.82 (131)

Five irrigations were given through the furrows on 6.11.81, 21.11.81, 27.12.81, 14.1.82 and 23.1.82. The plants were harvested within a few days of maturity from the entire plot, and 20 plants sub-samples were taken for the measurement of yield components.

Results and discussion

The plant population used this year was equivalent to 266,600 plants/ha, which is close to the optimum found in previous years (PPR 1980-81, Table 28, Fig. 21). Nevertheless, in spite of the fact that the plants were fertilized and were irrigated frequently, the growth and yield was unimpressive (Tables 24 and 25). The highest yield on both soils was given by cv. BDN-1, with 631 kg/ha on Alfisol and 603 kg/ha on Vertisol. The greatest amount of dry-matter on Vertisol was 1669 kg/ha (cv. C-11) and on Alfisol 1356 kg/ha (BDN-1).

Last year, with three irrigations the yield of cv. C-11 sown on Vertisol in October was 1440 kg/ha, and in November 900 kg/ha. The total dry weights were 3700 kg/ha and 2000 kg/ha respectively (PPR 1980/81, Fig. 20, Table 24)

This year in the trial described in Section XII, the irrigated rabi crop of cv. C-11 yielded 1090 kg/ha, with 3550 kg/ha total dry matter (Tables 38 and 39).

Why were the growth and yield in the present trials so poor, in spite of frequent irrigation? Part of the reason in the case of the Alfisol trial might be the relatively late planting, in early November. But the Vertisol trial was planted in October, and still yielded less than the trial planted in mid-November last year.

One reason for the low yield on Vertisol might be insect damage, owing to imperfect pest control. This was probably worst in cv. ICP-1-6, which had only 0.8 seeds/pod (Table 25). But even if the yield of this cultivar is doubled to make allowance for heavy pest infestation, it still comes to only 400 kg/ha. And pest attack on the pods would not explain the poor growth of the plants, reflected in the low total dry weight.

It would be tempting to ascribe the poor performance of the plants on Vertisol to some unidentified soil factor. But this trial was immediately adjacent to that described in Section III, in which the growtn and yield were good. So they cannot be explained away in terms of a 'bad field'.

The most plausible explanation for these results seems to be that the plants performed poorly not in spite of the frequent irrigation, but because of it. We have often observed that rabi pigeonpeas look unhealthy for a few days after they havebeen irrigated, with a distinct yellowing of the leaves. Four years ago we found that a single irrigation applied to rabi pigeonpeas had a tendency to reduce yield, and speculated that this could be due to the temporary creation of anaeorbic conditions within the soil (PPR 1977-78, Section VI. 5). Moreover, in Dr. H. Hirata's experiment, referred to below, growth analysis showed that vegetative and early reproductive growth was reduced by irrigation treatments, compared with non-irrigated controls, as was nitrogen and phosphate uptake. An additional reason for a harmful effect of irrigation on Vertisol may be because it cause the soil to swell. The cycles of shrinking and swelling caused by intermittent irrigation and soil drying could damage the roots and/or nodules.

On the other hand, we have ample data to show that growth and yield are increased by up to 3 irrigations. It may be that with a few irrigations the advantages outweigh the disadvantages; but frequent irrigation may have repeated harmful effects on the plants without giving much additional advantage over less frequent irrigation in charging the soil profile with water. The net effect could therefore be to reduce the growth and yield.

However, whatever the reasons, the results of this experiment suggest that the yields of rabi pigeonpeas cannot be raised to anew level simply by increasing nutrient and water inputs. This finding contrasts strikingly with the situation in chickpeas, where with high inputs, over 6000 kg/ha of total dry matter can be obtained, with seed yields in excess of 3000kg/ha (CPR 1980/81, Section V). It seems likely that a major reason for the difference between the two crops is their different temperature optima. The rabi season at Hyderabad seems to be too cool for pigeonpeas to grow and yield well, even when water, light and nutrients are not limiting; whereas it is, if anything, too warm for chickpeas, which perform even better in the cooler winters of north India.

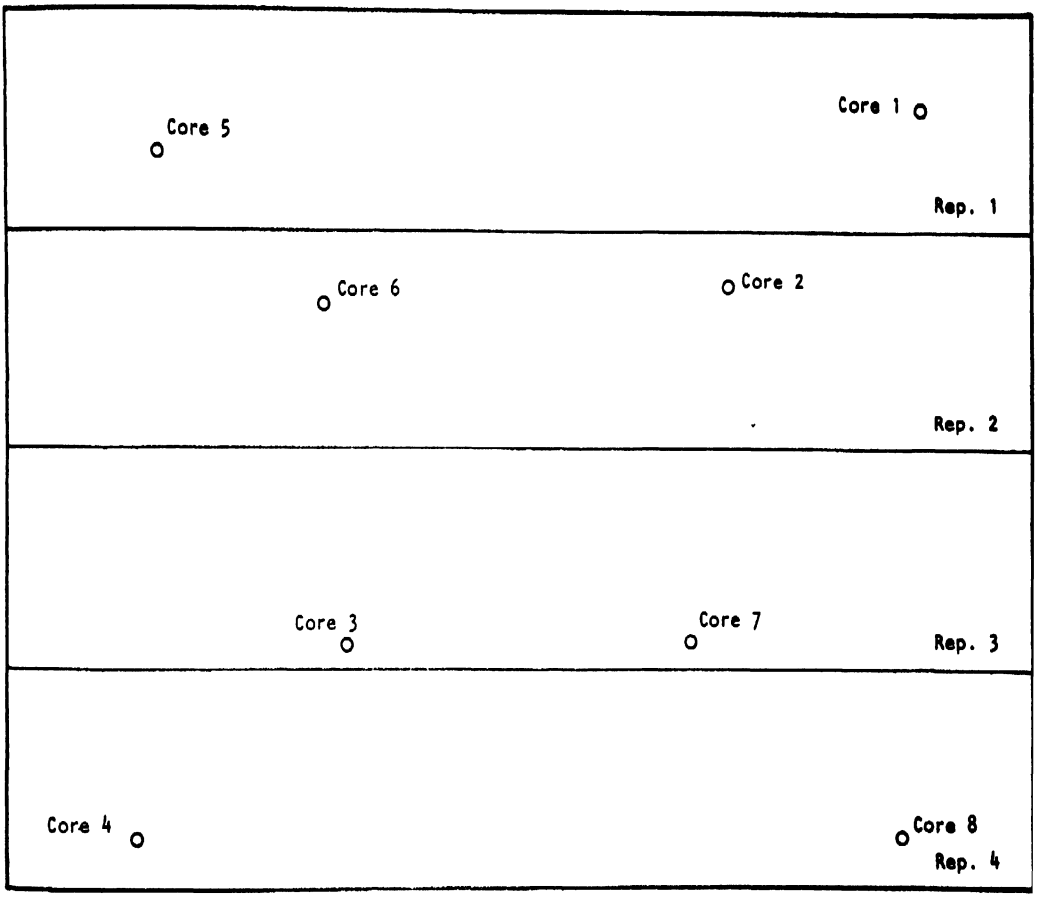


Figure 7. Lay-out for soil sampling positions in Saline field BS-8C.

Table 26. Analysis of soil samples taken from different depths at 8 sampling sites in field BS-8C.

Soilcore No.	Depth	pH	Ec* (mmhos/cm)	Ca (ppm)	Mg (ppm)	Na (ppm)	Exchangeable Na %
1.	0 - 30	8.75	0.48	5682	1172	907	8
	30 - 60	8.90	0.66	4313	1219	1938	17
	60 - 90	8.30	3.20	4800	1569	2200	19
	90 - 120	8.10	4.00	5700	1850	2450	21
2.	0 - 30	8.55	0.68	5175	1075	2525	22
	30 - 60	8.50	1.80	5250	1400	1825	16
	60 - 90	8.30	3.36	5813	1831	2200	19
3.	0 - 30	8.85	0.87	4500	950	1263	11
	30 - 60	7.80	2.38	4575	1250	2138	19
	60 - 90	8.50	2.19	4238	1550	2500	22
4.	0 - 30	8.10	3.80	7425	1144	2132	19
	30 - 60	8.05	2.62	8900	1669	2750	24
	60 - 90	8.40	2.80	5063	1438	2450	21
5.	0 - 30	8.50	1.54	4838	1206	1725	15
	30 - 60	8.30	3.60	4650	1638	2675	23
	60 - 90	8.10	5.50	5963	2025	2850	25
6.	0 - 30	9.00	1.00	3825	1125	1725	15
	30 - 60	8.30	6.00	6750	1794	3300	29
	60 - 90	8.35	6.99	7275	1750	3400	30
7.	0 - 30	8.60	0.85	5475	1169	1400	12
	30 - 60	8.30	2.40	4951	1509	2000	17
	60 - 90	8.50	2.48	4238	1738	2288	20
8.	0 - 30	8.65	0.30	5200	1000	2013	18
	30 - 60	9.00	0.40	4875	1075	975	8
	60 - 90	9.10	0.60	4875	1375	1888	16

is the reverse of that used last year in that higher scores indicate greater tolerance).

Observation	Score	
No emergence/almost all plants dead	1	Susceptible
Many plants dead and poor growth	2	Moderately susceptible
Few plants dead and poor growth	3	Slightly tolerant
Reduced growth with leaf necrosis, yellowing and shedding	4	Moderately tolerant
Normal growth and branching	5	Tolerant

Testing for salinity tolerance in pots

Artificially salinized soil was prepared as described previously (PPR 1980/81, p. 44) by mixing a powdered salts with dry Vertisol. The salts were in the ratio 7 meq NaCl: 1 meq Na_2SO_4: 2 meq $CaCl_2$. The initial EC value of the soil used, before the addition of salt, was 1.3 mmhos/cm in a 1:2 soil water extract.

The artificially salinized soil was placed in round plastic pots (5" diameter) perforated at the bottom, which was covered with muslin. The pots rested on 7" diameter saucers. The seeds were planted about 1 cm. deep, with 5 seeds per pot. There were 2 replicates for each treatment. The pots were kept in a screenhouse which was cooled during the day by evaporative coolers.

Watering the pots from the top led to leaching of the salts from the soil, and watering from the bottom (by pouring water into the saucers) led to an accumulation of salt at the surface of soil. Hence, a procedure was adopted whereby the pots were watered (with deionized water) alternately from the top and the bottom. This method appeared to be quite satisfactory.

In a preliminary experiment to ascertain the levels of salinity needed to differentiate between tolerant and susceptible cultivars, two cultivars, cv. C-11 (tolerant) and cv. HY-3C (susceptible) were grown in a range of salt levels from 0-60 meq/kg dry soil. The addition of 60 meq salt to 1 kg of dry soil gives an EC value in a 1:2 soil water extract of 3 mmhos/cm (PPR 1977/78, Figure 8). Sowing was carried out on 21.9.81.

Results and discussion

Field Screening

Though the salinity in the field was uneven (Table 26), the test lines could be compared quite easily with the tolerant and susceptible checks adjacent to them. These checks showed a satisfactory differential response, with much lower rates of survival in the susceptible than the tolerant check.

By visual scoring, 27 out of the 79 lines tested were rated as being at least as tolerant as cv. C-11, the tolerant check. They are listed in Table 27 (A list of the lines which were tested but found to be more susceptible than the tolerant check can be supplied on request). These lines also compared favourably with cv. C-11 by the more quantitative criterion of percentage survival. However, the counts of surviving plants did not seem to have any advantage over visual scoring as a means of assessing tolerance, and it will probably be unnecessary in future work to use both methods.

Some of the lines identified as tolerant this year were also found to be tolerant last year, which is encouraging is that it suggests this screening method is capable of producing consistent results.

Screenhouse method using young plants in pots

The advantage of a screening method that can be used with young plants in pots is that larger numbers of lines could be tested more quickly than in the field. Promising lines identified in this way could then be tested in the field to check whether the salinity tolerance was expressed under field conditions.

In a preliminary experiment, cvs. C-11 and HY-3C were tested at a range of salt levels. In both cultivars the growth of the plants were reduced at higher salt levels. The two cultivars showed a very satisfactory differential response in mortality (Table 28). Some mortality occurred in cv. HY-3C even in the non-salinized soil. This may have been because of the moderate natural salinity of the soil which was 1.3 mmhos in a 1:2 soil: water extract). These results show that testing for salinity tolerance in pots is feasible, and are being followed up. We plan to use the pot method for preliminary screening of breeders' lines and cultivars, and then check the performance of tolerant cultivars under field conditions.

Table 27. List of pigeonpea lines showing salinity tolerance under field conditions, 1981-82. Lines marked with an asterisk were also found to be tolerant in 1980-81.

Line No.	Source	Line No.	Source
ICPL-42*	ICP-185-9	ICPL-243	ICP-1 x JA-278
ICPL-43*	ICP-2223-1	ICPL-247	ICP-7035 x JA-278 x ICP-6997
ICPL-96	Group 2 x Group 9	ICPL-248	No. 148 x ICP-102
ICPL-97	Group 5 x Group 9	ICPL-264	ICP-8518
ICPL-133	BDN-2	ICPL-270	ICP-7855
ICPL-227*	ICP-1-6	ICPL-275	75091-1-1
ICPL-228	No. 148 inbred	ICPL-284	ICP-3773
ICPL-229	No. 148 inbred	ICPL-299	Pant A2 x NP(WR)-15
ICPL-230*	AS-71-37	ICPL-307	(Baigani x ICP-7035) x (ICP-6997 x ICP-7105)
ICPL-231*	AS-71-37 inbred	ICPL-308	SMP-25-4-B-B
ICPL-232	ICP-1 inbred	ICPL-309	SMP-39-31-B-B
ICPL-236*	ICP-102 inbred	ICPL-225	C-11 x ICP-6997
ICPL-238	ICP-6982 Selection	ICPL-245	(ICP-4726 x ICP-6) x JA-275
ICPL-239	ICP-3163 Selection		

Table 28. Mean percentage mortality of pigeonpea seedlings in pots at 30 days after planting.

Salt level (meq/kg dry soil)	Percentage mortality	
	cv. C-11	cv. HY-3C
0	0	11.1
15	0	33.3
30	0	50
45	0	50
60	33.3	100

VII. SCREENING FOR TOLERANCE TO WATERLOGGING:

Short term waterlogging is often a problem with pigeonpeas during the monsoon season. The identification of tolerant cultivars would be the cheapest and simplest answer to it. Genotypic differences in tolerance to waterlogging have been detected in screening done in modified paddy fields for producing waterlogging conditions (PPR 1978/79, Section IV. 3; PPR 1979/80, Section II; PPR 1980/81, Section V).

Since these paddy fields have now been used continually for growing pigeonpea, an inoculum of *Phytopthora* blight has built up in them. This disease is aggravated under waterlogging conditions and has prevented in from further screening in the rainy season in these fields. Screening in post-rainy season, which is usually less conducive to the development of *Phytopthora* blight, is therefore being standardised.

For large scale rapid screening, we continued working on the development of a pot technique. This is described below.

Materials and methods

Forty six *Phytopthora* blight resistant lines supplied by Genetic Resources Unit of ICRISAT and six advanced breeding lines (supplied by pigeonpea breeders) found to be promising in previous field screening were included in the test, as were 2 check cultivars, BDN-1 and HY-3C, tolerant and susceptible respectively. These were planted on 21st January 1982 in round plastic pots (7" diameter). The pots were perforated and lined with muslin at bottom and filled with steam-sterilized black soil. Five seedlings were raised in each pot, and there were 3 replications for each entry. The plants were allowed to grow with regular watering for 45 days in the open air. These pots were then submerged in water-filled plastic troughs to create waterlogging conditions for four days (on 7.3.82). The days during the waterlogging treatment were clear and maximum temperatures went up to 37° C.

After four days of waterlogging the pots were removed from plastic troughs. The excess water in pots drained out through perforations at bottom within a few hours.

Percent mortalities in different cultivars were recorded after relieving the waterlogging. Final observations were taken 10 days after relieving the waterlogging, during which time susceptible cultivars showed mortality. The pots were irrigated after waterlogging also, so as to avoid mortalities due to moisture stress.

Cultivars showing more than 25% mortality were considered susceptible.

Results and discussion

Screening for waterlogging tolerance requires more or less uniform waterlogging conditions. In paddy fields this has been achieved through arranging field drainage system 1 m below the soil. By opening the taps, excess water from the fields can be drained out quicker than is feasible by natural infiltration.

A comparable system has been developed for screening in pots. The plants grown in pots can be waterlogged for a defined period by putting them in the waterfilled troughs. Plants can be relieved from waterlogging by removing the pots from the troughs. Excess water drains out of the perforations at the bottom. Since the number and size of these perforations is similar, drainage is nearly uniform in all pots.

In the present screening, out of 46 *Phytopthora* blight resistant lines only 13 showed survival greater than 75% and only one advanced breeding line showed greater than 75% survival (Table 29). Waterlogging in pots under these conditions appeared to be severe, since the tolerant check cultivar BDN-1 also showed a high mortality. The weather during which the experiment was conducted was warm and sunny. From our previous experience warm and sunny days appear to be most conducive to waterlogging damage. Therefore January to March when temperatures are going to rise and there is little liklihood of overcast skies seem to be most suitable for screening for waterlogging tolerance.

Screening in pots in sterilized soil seems likely to be a useful and rapid way of identifying tolerant cultivars without the problem of *Phytopthora* blight. However, it is essential that cultivars found to be tolerant in pots should also be tested under field conditions, and this is now being carried out.

Table 29. List of promising waterlogging tolerant lines

Line	Mean percentage mortality
ICP-2974	0
ICP-1529	0
ICP-1788	0
ICP-7057	0
ICP-7151	7
ICP-6865	7
ICP-4135	7
ICP-580	13
ICP-5450	15
ICP-301	15
ICP-5860	20
ICP-1950	22
ICPL-81	22
ICP-2673	24

VIII. SELECTION FOR PHYSIOLOGICALLY ANNUAL PIGEONPEAS

In an attempt to find mutant pigeonpeas with a physiologically annual character, seeds of cv. BDN-1 were exposed to gamma radiation and seeds of cvs. BDN-1 and ICP-1-6 to a chemical mutagen, as described previously (PPR 1980-81, Section VI).

Last year over 0.5 ha of plants of the M_2 generation derived from irradiated seeds were grown, and 35 plants were found which died at the end of the reproductive phase without apparent disease symptoms. Their seeds were collected, and this year rows of single plant progenies were grown on Alfisol in field RP-4B at spacings of 75 x 30 cms in an area of 40 x 30 m.

In addition, the M_2 generation from bulked seeds from M_1 plants, grown from seeds treated with different concentrations of the mutagen EMS in 1980, were grown in field RP-4B in 40 x 10 m plots, and also on Vertisol in field BIL-2B in 48 x 5 m plots.

At the time of maturity, dead plants were removed from the field and examined by Dr. J. Kannaiyan, Pulse Pathologist, for symptoms of the wilt disease. Plants which had died without apparently suffering from disease were harvested separately. Altogether 10 such plants were found in the M_3 generation derived from irradiated seed, and 30 plants in the M_2 generation of cv. BDN-1 derived from seeds treated with 0.4% EMS. None were found in the other plots.

Seed was also collected from the wilted plants in each plot. Such plants were quite numerous in the Alfisol field.

Single plant progenies from the dead plants apparently free from disease are being tested in 1982-83, as are plants derived from the bulked seeds of wilted plants. These will again be observed to see if any die at the time of maturity for physiological rather than pathological reasons.

IX. SECOND HARVEST YIELDS OF INTERCROPPED PIGEONPEAS ON ALFISOL

Higher second harvest yields are usually obtained on Alfisol than on Vertisol (PPR 1980-81, Section VII). Moreover, on Alfisol considerable yield increases can be obtained with a single irrigation (PPR 1977-78, Section IV.2; PPR 1978-79, Section V.2). This might prove to be of practical value in situation where some irrigation water is available in December or January. An analysis carried out by the ICRISAT Economics Unit suggests that such a practice could be both feasible and profitable, for example in Alfisol watersheds with tanks.

Our previous data were obtained with sole cropped pigeonpea. This year we evaluated the second harvest yield and response to irrigation of pigeonpeas which had been intercropped with sorghum on broad beds.

Materials and methods

Pigeonpea cv. ICP-1 was grown as an intercrop, sown during the last week of June 1981, with sorghum on broad beds in field RCW-16B. There was a row of sorghum on each side of each bed, and a row of pigeonpea in the centre. Hence the pigeonpea rows were 150 cm apart. The sorghum was harvested in October. This experiment was sown by the Farming Systems group and handed over to Pulse Physiology when the pigeonpea matured in December.

Twelve plots of 6 x 10 m were marked out, and the first harvest was taken on 17.12.81 by ratooning the plants at a height of 1.5 m; this process was carried out using the small sickles normally used by labourers.

Following a fully randomized design, 6 out of the 12 plots were irrigated on 22.12.81 through the furrows between the broad beds. The second flush of pods on the irrigated plants matured by 11.3.82, a few days later than the unirrigated plants, and the trial was harvested on 18.3.82. The effects of irrigation on yield were analysed statistically using Student's 't' test for equal sized samples.

Results and discussion

The mean first harvest yield from this experiment was 731 kg/ha, which is typical of intercrop pigeonpea yields on Alfisol.

The second harvest yield without irrigation was 211 kg/ha, and with irrigation 332 kg/ha. (The difference due to irrigation was statistically significant at the 5% level). Thus irrigation led to a 57% increase in second harvest yield; and this second harvest yield was 45% of the first harvest yield.

These results confirm that worthwhile second harvest yields can be obtained on Alfisol, and that a single irrigation can increase yields substantially. However, such a system may not be profitable with intercropped pigeonpea, since the plant population is so low. In order to make the best use of available irrigation water, it would be better to use a sole crop of pigeonpea or at least use an intercropping system with a higher proportion of pigeonpeas.

X. EFFECT OF SOIL CRACKING ON THE YIELD OF PIGEONPEAS

Second harvest yields, which are produced by pigeonpeas about 3 months after the maturity of the first flush around December, are much lower in Vertisol than on Alfisol (PPR 1980/81, Section VII) This is surprising since during this period the growth of the plants largely depend on moisture stored in soil profile and Vertisols, owing to their greater water-holding capacity, contain more moisture than Alfisols at this stage (PPR 1980/81, Section VII).

On the basis of circumstantial evidence obtained in chickpea (CPR 1979/80, Section XII) and experiments carried out in pigeonpea (PPR 1980/81, Section III and VII) we hypothesized that the low yields on Vertisol may be due to cracking of soil which characteristically occurs as the post-rainy season advances.

The pattern of cracking depends on the method of land preparation and is particularly influenced by soil compaction. We carried out this experiment on broad-beds and furrows, in which cracks develop predominently in the furrow zone between the beds as a result of wheel pressure from the bullock-drawn "tropicultor". Three rows of pigeonpeas were planted on each broad-bed, and the growth and yield of the plants in the centre rows was compared with those in the side rows, which were closer to the cracks in the furrows. The experiment was conducted both with and without mulches placed in the furrows over the cracking zone during the post-monsoon season.

Materials and methods

This experiment was carried out in conjunction with Mr. K.L. Srivastava of the Farming Systems Program. On 19.6.81, three rows of pigeonpea (cv. C-11) were planted 50 cms apart with a plant to plant spacing of 20 cms on each 150 cms wide broad-beds running in a North-South direction in Vertisol field BW-5. Thus each broad-bed had a row of pigeonpeas on its east side, in the centre and on the west side. Three main treatments, control (without mulch), mulching with rice straw in the furrows in October (30.10.81) and mulching in January (4.1.82) were randomised among six replications. In the control plots, the fallen leaves were removed from the furrows on 20.11.81 and 4.1.82 to reduce their natural mulching effect. The net plot size (excluding border broad-beds) was 6 m long with 3 broad-beds in each treatment. Each row was harvested separately. The cracking pattern was recorded by the Farming Systems group.

The plants reached the 50% flowering stage on 29.10.81 (132 days after sowing) and the first crop matured by 24.12.81 (188 days). The first harvest was taken row-wise on 1.1.82 by pod picking, and the second flush of pods was harvested on 19.3.82 when the weight of the shoot system and the yield, pod number and seed number were recorded for each row in every plot.

Results and discussion

There were no significant effects of the mulching treatments (Tables 30-32). One reason for this may be that under the well-developed canopy within the plots, relatively little evaporation occurred from the soil. Another reason may be that the main effects of soil cracking on the plants were due to the tearing and shearing of roots rather than an enhanced evaporation of water from the cracks in the soil.

As expected, cracks developed mainly within the furrows, and thus in general the pigeonpeas in the rows on the sides of the broad-beds were closer to cracks than the plants in the cetnral rows (Fig. 8).

There was a striking difference in yield between the rows. The central rows yielded considerably more than the rows on the sides of the broad-beds, and of the rows on the sides, those on the east yielded significantly more than on the west. This pattern was clearly apparent in both the first and second harvests (Tables 30 and 31), and also in the total dry weight of the plants at the time of second harvest (Table 32).

There was no significant difference in the plant population in the east, central and west rows, and consequently the significant differences in yield and total dry weight per hectare were paralled by similarly significant differences in yield and total dry weight per plant.

There was no significant effect of row position on hundred-seed weight or seed number per pod; the yield differences between the rows were almost entirely due to differences in pod number per plant.

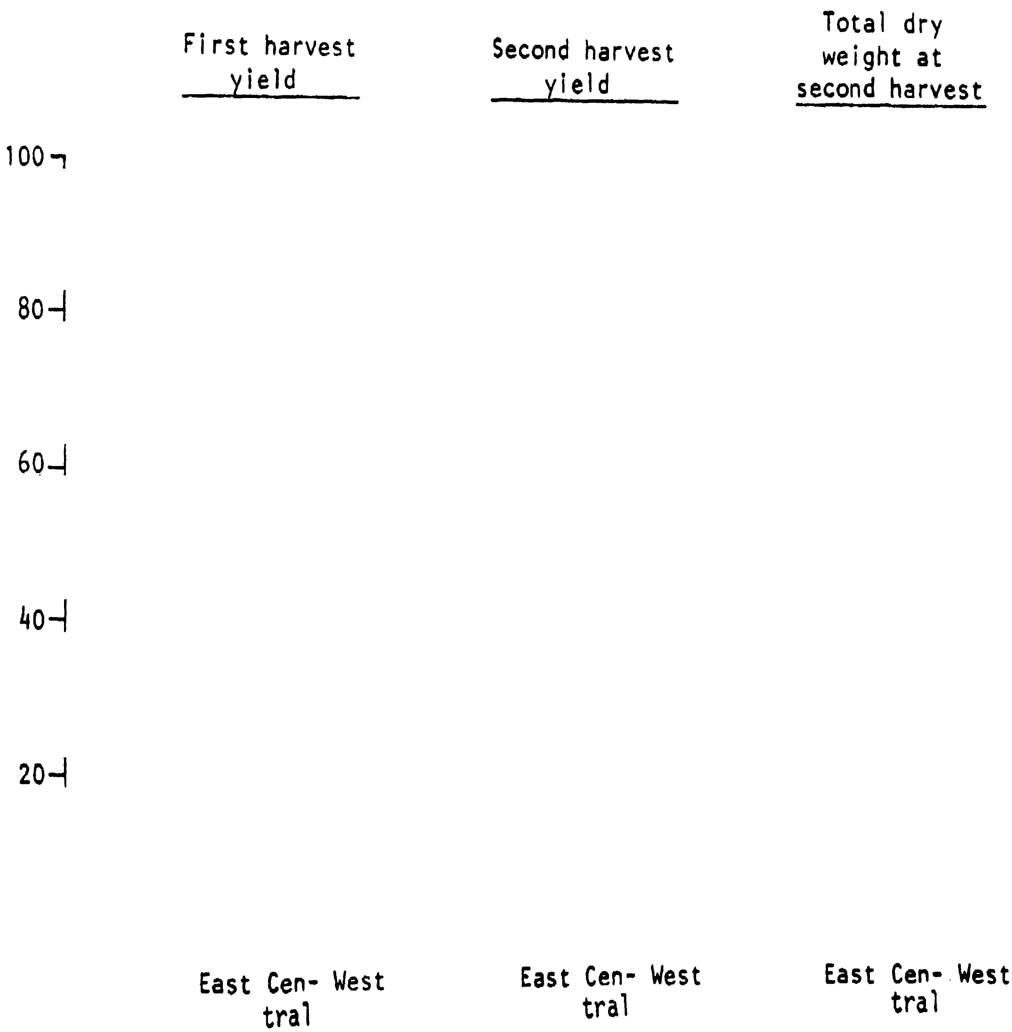


Figure 8. Yields and total dry weight of pigeonpeas in rows on the east and west sides of broad beds relative to central rows.

Table 30. Effect of soil cracking on first harvest yield of pigeonpea.

	Yield/ha (kg)			
	Eastern Rows	Central Rows	Western Rows	Mean
Control	1911	2378	1524	1938
Mulching in October	1870	2401	1485	1918
Mulching in January	1808	2395	1496	1900
Mean	1863	2391	1502	
SE		± 59.12		± 52.6

The standard error for comparing rows at a given level of mulching is ± 98.8 and for comparing mulching at the same level of rows ± 102.4.

Table 31. Effect of soil cracking on second harvest yield of pigeonpea.

	Yield/ha (kg)			
	Eastern Rows	Central Rows	Western Rows	Mean
Control	309	401	276	329
Mulching in October	284	400	199	294
Mulching in January	244	344	179	255
Mean	279	382	218	
SE		± 14.40		± 28.57

The standard error for comparing rows at the same level of mulching is ± 35.09 and for comparing mulching at the same level of rows is ± 24.94.

Table 32. Effect of soil cracking on total dry matter recorded at the time of second harvest.

	Total dry matter(kg/ha)			
	Eastern Rows	Central Rows	Western Rows	Mean
Control	5746	6673	4930	5783
Mulching in October	5750	7219	4286	5752
Mulching in January	6019	6784	4563	5789
Mean	5838	6892	4593	
SE		±158.2		±199.1

The standard error for comparing rows at the same level of mulching is ± 299.5 and for comparing mulching at the same level of rows is ± 274.0.

Table 33. Yields of side and centre rows of sorghum and millet grown on broad-beds on Alfisol. Data from ICRISAT Farming Systems Farm Power and Equipment Reports (by M.C. Klaij, 1981 and N.K. Awadhal, 1982).

Year	Field	Yield (kg/ha)		Side rows as % of centre rows
		Side rows	Centre rows	
MILLET				
1978	RA-14	635	988	64
1981	RM-16A	1882	2131	88
1982	RP-19B	1868	2061	91
SORGHUM				
1979	RA-14	2090	2241	93
1979	RW-2B	3176	2890	110
1980	RA-14	926	1127	82
1980	RW-2B	1928	1534	126
1981	RP-19B	2770	3183	87

The lower yields in the rows on the sides of the broad-beds than in the centre seems likely to be due to the damaging effects of cracks which developed mainly within the furrows. These cracks develop after the end of the rains and therefore their damaging effects might be expected to become more pronounced as trial goes on. That this was the case is suggested by the greater proportionate reduction in the yields of the side rows relative to the centre rows in the second harvest than in the first (Fig. 8). There was a smaller effect of row position on total dry weight than yield (Fig. 8) which may be due to the fact that much of the dry weight in the vegetative structures was accumulated before soil cracking began during the post monsoon season.

Although the second harvest yields were higher in the central rows than in the side rows, they were still relatively modest compared with those which can be obtained on Alfisols (PPR 1980/81, Table 18). Since some cracking appeared within, especially across, the broad-beds, the yields of the plants in the central rows may also have been reduced by cracking, although not so much as those on the sides of the beds beside the furrows. However, it remains an open question as to whether cracking alone is sufficient to account for the generally poorer second harvest yields on Vertisol than on Alfisol.

The striking differences between the east and west rows are similar to those found last year between rows planted on the two sides of 75 cms ridges on Vertisol (PPR 1980/81, Figure 7). We suggested then that although the plants both sides of the ridges were equally close to the cracks in the furrows, those on one side may have been affected more than on the other side owing to an asymmetrical distribution of the root system (PPR 1980/81, p. 29). During the early stages of growth, the strong prevailing westerly winds lead to a marked asymmetry of shoot development, with more branches on the west than on the east side of the plants; this could well be associated with an asymmetric development of roots. If there were more on the west than the east, pigeonpeas growing in the rows on the west of the broad-beds would be particularly badly affected by cracking in the furrows. We are at present checking this hypothesis by direct measurements of the pattern of root distribution and also through artificial root cutting as east and west side of the pigeonpea rows.

The deleterious effect of the cutting of roots on the yield of pigeonpeas was demonstrated directly in an experiment carried out this year by Mr. K.L. Srivastava of the Farming Systems group. In a pigeonpea crop (cv. C-11) grown in Vertisol and irrigated during

November, plants in some of the plots had their roots cut by hammering a metal plate into the soil to a depth of 20 cms at a distance of 15 cms from each row. The yield of these plants was 2129 kg/ha compared with 2635 kg/ha in the control plots; this yield reduction was statistically significant (LSD (5%) = 278). The root cutting treatment was imposed only during the third week of November when the plants' reproductive phase was already well advanced, and so the yield-reducing effects would probably have been greater if this treatment had been imposed earlier.

One note of caution is necessary in interpreting these results as evidence for soil cracking effects. On broad beds, compaction in the furrows may reduce yields of side rows directly, as may be shown by results from Alfisols obtained by the Farming Systems group with Sorghum and Millet grown in the monsoon season (Table 33). However, the effects they found were smaller than those detected here, and in sorghum in 2 cases out of 5 the side rows actually yielded more than the centre rows. A better growth of side rows than centre rows has also been observed with millet by the ICRISAT Millet Breeders (D.J. Andrews, Personal communication). Nevertheless, in future work it will be necessary to check the effects of compaction *per se* on side rows of pigeonpeas. This could be done by measuring growth before cracking begins, and also by measuring growth and yield under irrigated conditions in which cracking is suppressed.

In some experiments conducted by the ICRISAT Farming Systems scientists, the effects of growing pigeonpea-sorghum intercrops were compared growing 2 pigeonpea rows either along the sides of the beds with 2 sorghum rows in the centre, or with the pigeonpea rows in the centre and the sorghum on the outside. In 1979/80, the pigeonpea yields were somewhat higher (998 kg/ha) with the rows on the outside than in the centre (929 kg/ha), but the differences were not statistically significant (Cropping Systems Report 1979/80, Table 3). In 1980/81, there was a reverse tendency with a higher yield from the pigeonpeas as centre rows (943 kg/ha) than as side rows (919 kg/ha) but again the difference was not statistically significant.

These results are of considerable interest. With the pigeonpea rows on the sides of the beds, growth and yield might have been expected to be better for two reasons. First, before the harvest of sorghum, the pigeonpeas were able to make use of the 60 cms space between beds, whereas the pigeonpeas on the centre of the beds were flanked by sorghum rows 30 cms away which would have subjected them to more competition. Secondly, after the sorghum harvest, pigeonpeas in side rows 90 cms apart would have been less subject to row-to-row competition than the centre rows 30 cms apart. But in spite of these advantages, the pigeonpeas in side rows did not yield significantly better than in centre rows. This could be because their advantages were offset by the fact that they were closer to the furrows, and hence more affected by soil cracking.

XI. RABI-KHARIF-RABI PIGEONPEAS: A PERENNIAL CROPPING SYSTEM

Pigeonpeas as a post-rainy (rabi) season crop on deep Vertisols is well established in areas where temperatures in this season are conducive for good growth.

A new kind of cropping system becomes possible by growing a rabi crop of pigeonpea by planting around October and harvesting it by ratooning in late February or March and leaving the plants in the field. Owing to their deep root system and perennial nature, many of them survive until the onset of monsoon, and quickly establish a full canopy. A second harvest from this crop can be harvested in December without additional expense for cultivation or planting. A third harvest can then be obtained from the same plants in February or March when the crop can be removed from the field (Fig. 9).

The feasibility of the system was demonstrated in 1975/76 (PPR 1976/77, Section IV.3) and subsequently. However in the absence of disease resistant cultivar, the trials were vitiated by diseases, chiefly sterility mosaic. With the availability of an agronomically suitable disease resistant cultivar, ICP-1-6, the system was again tested in 1980-81-82. We also evaluated different cultural practices that might be useful for this cropping system.

Materials and methods

The trial was conducted at Sangareddy fruit research station in conjunction with Andhra Pradesh Agricultural University. After a preparatory tillage cv. ICP-1-6 was planted in Vertisol on 9.11.80 and a light 'come-up' irrigation, was given, since the surface layers of the soil had dried out by the time of planting. The spacing was 30 x 10 cms, giving a density of about 33 seeds/m^2. The area sown was 0.5 ha. No fertilizer was applied at any stage of the crop growth, nor were any further irrigation given.

The crop reached the 50% flowering stage on 5.2.81 (88 days after sowing) and matured on 15.3.81 (127 days after sowing). This rabi crop was harvested on 26.3.81.

In order to evaluate different cultural practices the whole trial was devided into 3 subsets of experiments.

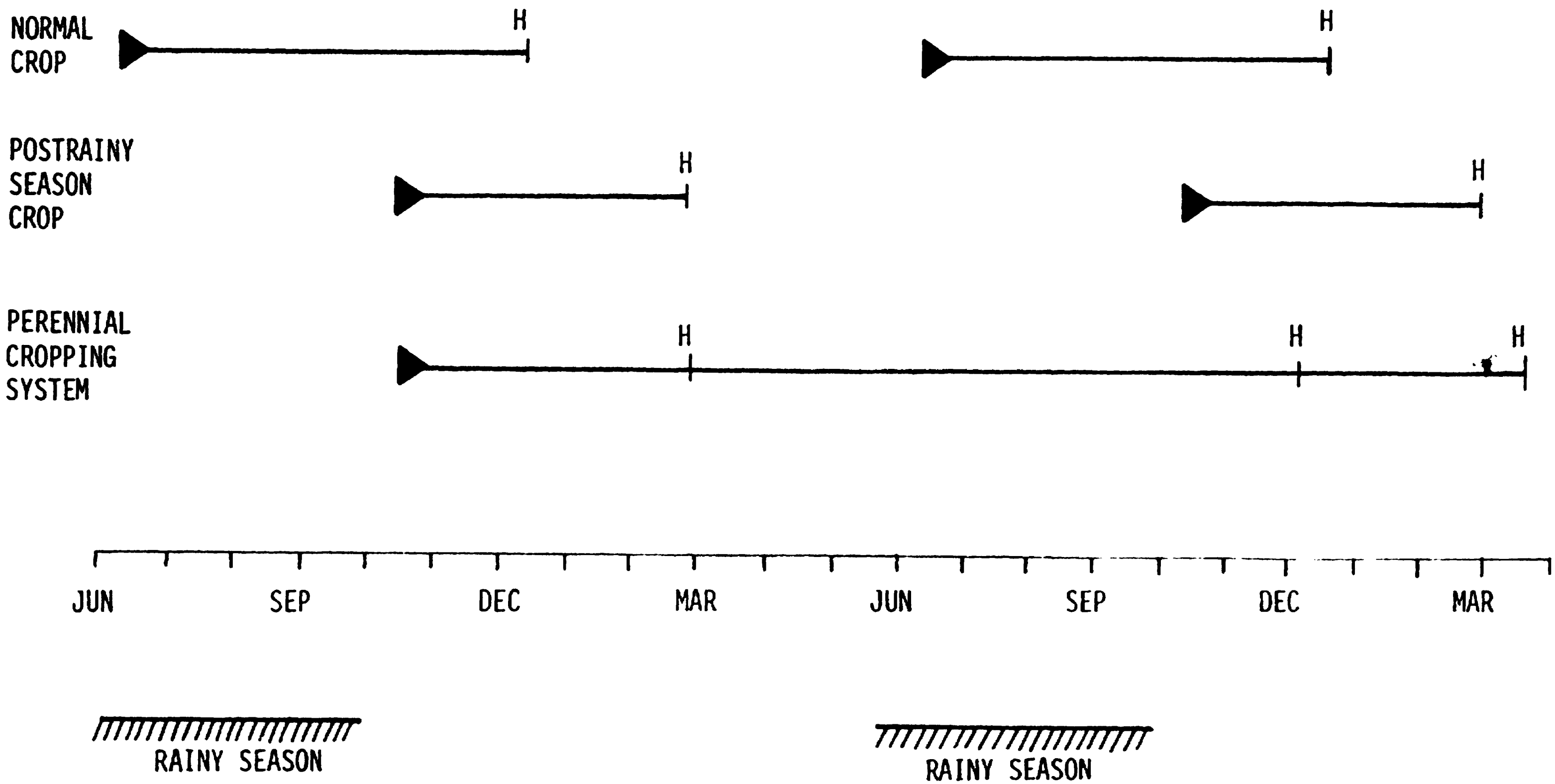


Figure 9. Diagrammatic representation of the perennial pigeonpea cropping system starting in the postrainy season, compared with the normal and postrainy season annual cropping systems with medium duration cultivars. Times of harvest are indicated (H).

Experiment 1: The first rabi crop was harvested in three different manners.

1. Pod picking
2. Ratooning at 10 cms from ground level
3. Ratooning at 30 cms from ground level

These treatments were laid in a randomized block design with four replications. Subsequent crops in December and April were harvested uniformly in each plot by ratooning at a height of about 150 cms and 10 cms above the ground respectively.

Experiment 2: The first harvest of this experiment was made as bulk by picking the pods. The following thinning treatments were imposed on 25.8.81.

1. No thinning
2. Removal of alternate rows
3. Removal of two rows out of every three rows.

Again the design was RBD with 4 replications.

Experiment 3: As in Experiment 2, harvest of plant rabi crop was made by picking the pods as bulk. Different methods of harvesting for kharif crop adopted were:

1. Pod picking
2. Ratooning at 100 cms from ground level
3. Ratooning at 150 cms from ground level

The treatments were laid in a RBD with 4 replications.

The plot sizes in Experiments 1, 2 and 3 were 55.0, 44.6 and 44.6 m^2 respectively. A hand weeding was done during the first rabi crop. A single insecticide spray (endosulfan) to control pod borer attack was applied during reproductive period of first rabi crop. Thereafter no further spraying and indeed no operations other than harvesting were undertaken. The kharif crop reached 50% flowering on 10.11.81 and matured on 22.12.81, when it was harvested. The subsequent crop from the new flush of pods matured on 5.4.82.

Results

The first harvest in March 1981, yielded around 400 kg/ha, which is quite normal for a late-sown rabi crop. With more timely sowing, in September or October, yields of well over 1 ton/ha are generally obtained (PPR 1977/78, Table 66; PPR 1980/81, Table 33).

During the summer season following the harvest of the rabi crop, considerable plant mortality occurred, mainly due to Rhizoctonia bataticola. The percentage mortality was 53% in control plots, 52% in those ratooned 30 cms above the ground at the end of the rabi season, and 57% in those ratooned at 10 cms. Thus ratooning had little effect on mortality and survival of the plants, which is fortunate since harvesting the rabi crop by picking the pods would be too time-consuming to carry out in farmers' fields.

In spite of these high mortality rates, owing to the dense planting of the rabi crop, the surviving plant population was on average still 2-3 times greater than is normally necessary for a kharif crop.

With the pre-monsoon and monsoon rains, the surviving plants grew rapidly and soon formed a closed canopy, which tended to smother weeds. No weeding was carried out, and nor were any plant protection measures. The plants suffered from an attack of spider mites in the late monsoon season, which caused yellowing of the leaves, but this infestation spontaneously abated, and growth was excellent. By the time of the December harvest the plants were 2.0-2.4 m high.

During the reproductive phase, some attack by the pod-boring caterpillars of Heliothis armigera was observed, but this was modest in scale. Far worse infestation was observed on kharif-sown pigeonpeas in nearby farmers' fields. Perhaps a higher population of natural parasites and predators had built up in our long-duration crop, keeping pod-borers in check.

The yield of the kharif crop, harvested in December in control plots was 1250-1450 kg/ha, which is similar to that obtained from a normal kharif sown crop.

A further harvest, taken in March, gave yields of only 100-140 kg/ha, comparable to second harvest yields at ICRISAT Center on Vertisol. These low yields may be due in part to the cracking of the Vertisol on which the plants were grown, and also due to the relatively high incidence of insect damage to the pods in this flush. Observations by the Pulse Entomology revealed that 70% of the pods were damaged; 48% by pod borers, 10% by pod fly and 16% by hymenopteran pests.

1. Ratooning at the time of harvest of the rabi crop:

Ratooning at the time of harvest of the first rabi crop had no significant effect on plant mortality (see above). Nor was there any significant effect on the yield of the subsequent kharif crop, harvested in December, nor on the ratoon crop harvested the following April (Table 34).

The average weight of fallen leaves within the plots at the time of harvest in December was high, 3100 kg/ha. These fallen leaves contained 1.33% nitrogen and 0.07% phosphorus, and thus would have added back to the soil 41 kg/ha of nitrogen and 2.2 kg/ha of phosphorus.

The dry weight of stems at the time of final harvest in April was 4677 kg/ha.

The seed number per pod and 100-seed weight were not significantly affected by the treatments. Their mean values in the rabi, December and subsequent ratoon harvests were 2.5, 2.3 and 1.6 respectively for seed number per pod; and 7.0 g, 10.2 g and 7.9 g for 100-seed weight.

2. Thinning of the crop during August:

This experiment was undertaken to find out whether the yields in the December harvest would be improved by reducing the plant populatic and also to estimate tne quantities of green fodder which could be harvested in this way during the monsoon season.

The fresh weight of the shoots harvested by thinning in August were 3122 kg/ha with the removal of alternate rows, and 4494 kg/ha with the removal of two rows out of every three. The respective dry weights were 812 and 1211 kg/ha.

There was a tendency for the thinning treatments to reduce the yield of the main kharif crop and the subsequent ratoon crop (Table 3! but these effects were not significant at the 5% level of probability.

The weight of fallen leaves at the time of the main harvest in December was reduced considerably by the thinning treatments, from 2127 kg/ha in the control plots, to 1531 kg/ha after alternate row removal, and 990 kg/ha after removal of two rows out of every three.

Table 34. Effect of different heights of ratooning of the rabi crop on subsequent yields in the rabi-kharif-rabi cropping systems.

Method of harvesting rabi crop	Yield (kg/ha)			
	Rabi (March 1981)	(December 1981)	Rabi (April 1982)	Total
Control (pod picking)	352	1449	131	1932
Ratooning at 30 cms	400	1437	110	1947
Ratooning at 10 cms	423	1214	112	1749
Mean	392	1367	118	1876
SE	±33	±101	±16	
LSD (5%)	NS	NS	NS	
CV %	17	15	27	

Table 35. Effect of thinning in August 1981 on subsequent yields in the rabi-kharif-rabi cropping system.

Thinning treatment	Yield (kg/ha)			
	Rabi (March 1981)	Kharif (December 1981)	Rabi (April 1982)	Total
No thinning	430	1252	110	1791
Thinning of alternate rows		1098	82	1609
Thinning of 2 out of 3 rows		930	77	1436
Mean		1093	90	1612
SE		±130	±9	
LSD (5%)		NS	NS	
CV %		24	20	

Weed growth was considerably greater in the thinned than in the control plots.

3. Effect of ratooning at the time of the December harvest:

We have generally found that harvesting the main kharif crop of pigeonpeas by picking the pods gives higher second harvest yields than ratooning (e.g. PPR 1980/81, Section VII). The main reason for the reduced yield in the ratooned plants is probably because vegetative regrowth delays the second flush of flowering in a period when the plants are subjected to increasing moisture stress.

In this experiment too, ratooning reduced the subsequent yield, and plants ratooned closer to the ground yielded less than those ratooned higher up (Table 36). However, the yields were in all cases low, and the additional cost of pod picking compared with ratooning would hardly be justified for a yield advantage of a mere 46 kg/ha.

Discussion

This experiment clearly shows the feasibility of the rabi-kharif-rabi cropping system. In large tracts of peninsular India where Vertisols are left fallow during the monsoon, this system would have major advantages. After taking a rabi crop of pigeonpea, the plants could go on to give a good yield after the subsequent monsoon, with little or no further cultivation or weeding cost This crop would also improve the soil by adding back as much as 41 kg/ha of nitrogen and provide a useful supply of firewood.

The main expense might be in protecting the crop from grazing after the first rabi harvest. However, if the plants are harvested by ratooning there is not much left for animals to graze on; and it is possible that the plants would survive even if they were grazed. We attempted to investigate this in the present experiment by having a part of field unfenced; since animals enter the Sangareddy farm from time to time, this unfenced area probably would have been grazed to some extent. The yield of this area in the main December harvest was 1032 kg/ha, somewhat less than the control yield in the adjacent experiment 3 of 1246 kg/ha, but this could have been due to the generally poorer growth in area which was unfenced, rather than to the limited grazing the plants were exposed to. A more realistic test of the effects of grazing during the summer season should be carried out in farmers' fields.

Table 36. Effect of different ratooning methods at the time of harvest of the main crop in December 1981 on subsequent yield.

Ratooning treatment (December 1981)	Yield (kg/ha)			
	Rabi (March 1981)	Kharif (December 1981)	Rabi (April 1982)	Total
Pod picking	430	1246	140	1816
Ratooning at 175 cms		1017	94	1541
Ratooning at 100 cms		1098	65	1593
Mean		1120	100	
SE		± 95	± 11.5	
LSD (5%)		NS	39.7	
CV %		17	23	

Note: the single Rabi (March 1981) value of 430 is bracketed across all three treatments.

Although a good yield was obtained after the monsoon without insecticide spraying, it is possible in other years more damage might occur. The system is currently being tested again at ICRISAT Center under unsprayed conditions.

The results of the first experiment show that the first rabi crop can be harvested by ratooning, which is an encouraging finding, since this is much quicker and cheaper than pod-picking.

The results of the second experiment indicate that there may be no advantage in thinning the plant stand during the monsoon season. First, the fodder is of little value at that time, and would probably be difficult to dry; second, the yield is not improved; third, the growth of weeds is less effectively suppressed; and finally, the amount of fallen leaves is reduced.

The third experiment shows that the additional flush of pods after the main harvest is very modest, as we have found in other experiments on Vertisols; it may not be worth leaving the plants in the field when the extra yield is so small. Although pod picking gave higher subsequent yields than ratooning, the yield advantage would probably be too small to justify the extra cost and effort.

Further experiments to test this cropping system in different locations will be necessary before it can be extended to farmers' fields, but at present it seems extremely promising.

XII. RESPONSES OF PIGEONPEAS GROWN IN THE RAINY AND POST-RAINY SEASONS TO IRRIGATION

Pigeonpeas can be grown both as a rainy season as well as a post-rainy season crop in peninsular India on Vertisols. The total crop growth duration differs considerably in the two seasons, and so does total biomass production. Nevertheless, the post-rainy season crop, in spite of its short duration, can give comparable yields under favourable condition of moisture (PPR 1976-77, Section IV. 4, p. 137). This is by and large due to greater partitioning of dry matter into grain as is evident by high harvest indices. Harvest indices as high as 50% have been recorded in irrigated post-rainy season pigeonpea (PPR 1979-80, Section VIII, Table 31). Large responses to irrigation in yield of post-rainy season pigeonpea indicate that the growth of this crop is limited by soil moisture (PPR 1980-81, Section VIII).

The rainy season crop usually develop fairly deep roots (>1.5 m) by the end of monsoon season which are capable of extracting moisture from the deeper layers of the soil profile in the following dry season. In contrast, post-rainy season pigeonpeas grow on receding moisture. Information on their comparative water use, water use efficiency and response to supplemental irrigation is lacking. The present experiment was conducted in conjunction with Dr. Sardar Singh, Soil Physicist to obtain information on these aspects. The first section deals with responses to supplemental irrigation. Data on moisture extraction patterns and water use efficiency will appear in a later report.

Materials and methods

The experiment was conducted in a deep Vertisol field, BW-3. Neutron probe sampling tubes (157 cms deep) had been placed in the field 4 years previously.

Prior to sowing in June, the field received a basal dose of 100 kg/ha diammonium phosphate. In addition to this, a top dressing of 62 kg/ha N (as urea) was applied to the sorghum rows at 25 days after planting.

The trial was laid out in a split-plot design with irrigation treatments in the main plots and crops as sub-plots (size 10 x 10 m).

There were 4 replications. However, owing to a severe incidence of the wilt disease, rep. I was dropped from the analysis of yield components.

The crops were sown in flat seed beds. Pigeonpea cv. C-11 was used. The rainy season crop was planted on 18.6.81 by a bullock drawn tropicultor, with sole pigeonpea at 45 cms row spacing. Intercropped pigeonpea was at a 135 cms row spacing, with two rows of sorghum (CSH-5) 45 cms apart in between, with a plant-to-plant spacing of 10 cms. The pigeonpea seedlings were thinned to spacings of 45 x 45 cms and 135 x 15 cms, giving about 5 plants/m^2 in both cases.

The post-rainy season pigeonpea crop was planted by hand at a 30 x 10 cms spacing on 14.10.81, giving 33 seeds/m^2. The plots for the postrainy season sowings were kept weed-free prior to planting.

The irrigated plots of the rainy season crops received 2 flood irrigations 156 and 180 days after sowing (on 20.11.81 and 14.12.81). The postrainy season crop received 3 flood irrigations 36, 60 and 84 days after sowing (on 20.11.81, 14.12.81 and 7.1.82). Dates of flowering and maturity are given in Table 37.

Growth patterns were monitored by destructive growth analysis at approximately 20-day intervals on 5 adjacent plants sampled from each replicate plot from the 35-day onwards. Leaf area was measured on an automatic area meter.

The intercropped sorghum was harvested on 29.9.81, the rainy season pigeonpea crop on 26.12.81, and the postrainy season crop on 8.3.82. At the time of harvest, yield, yield components and total dry weights were recorded from net plots of 9.4, 12.0 and 10.2 m^2 in sole, intercrop and postrainy season crops respectively. These small areas were selected from regions of the subplots where the incidence of the wilt disease was minimal.

Soil moisture measurement was made by Dr. Sardar Singh of the Farming Systems Program at regular intervals by means of nutron probes.

Light interception by the crop was measured using 90 cms long solarimeter tubes (ΔT, USA) between 11.00 A.M. and 2.30 P.M. at about 15 days intervals. These tubes were connected to integrators with electric wires which quantified incoming solar radiation, in the form of counts. After calibrating these tubes in open place in the field for 4 minutes, two of these tubes were placed under the crop canopy on the ground at right angles to the rows positions, to measure radiation penetrating the canopy, a third (control) was left outside to measure total incoming radiation. Integrated counts over two minutes period from the tubes under the canopy and the one kept outside the canopy were recorded simultaneously. After correction of counts using the factor calculated from calibration for each tube, the following formula was used to calculate the light interception:

$$\text{Light interception} \quad 1 - \frac{\text{Mean corrected counts under the canopy}}{\text{Corrected control tube counts}} \times 100$$

Results and discussion

Growth pattern

The pigeonpeas sown as a sole crop in June showed a similar pattern of development to that observed in previous growth analysis (e.g. PPR 1974-75, Fig. 3; PPR 1975-76, Fig. 12; PPR 1976-77, Fig. 2). There was less net loss of leaves in the plants which were irrigated during the reproductive phase (Fig. 10).

The pigeonpeas intercropped with sorghum showed a much slower rate of growth than the sole crop, as would have been expected (Figures 10 and 11). These growth analysis data show a considerable response to irrigation in growth and pod development in the pigeonpeas which had been intercropped. However, in the data on dry weight and yield from the plot harvests, no such benefit of irrigation was apparent (see below). This discrepancy between the growth analysis and plot harvest data is probably explicable in terms of the large sampling errors involved in selecting the 5 plant samples for growth analysis. Once again it emphasizes the need for taking larger samples from an area of several square meters, and this system of taking larger samples will be adopted in future work.

The data on leaf area index show the sole crop reached a maximum of just over 4 soon before flowering began, and leaf area declined to around 0.5 at the time of harvest (Fig. 12). In the intercrop LAI continued to increase during the first half of the reproductive phase, but the maximum was only 2.

... throughout the growing season of pigeonpea (cv C-11) grown in the rainy season as a sole crop. Dates of flowering (F) and irrigation (I) are indicated by arrows. L+P = leaves + petioles; S = stem, R = reproductive structures.

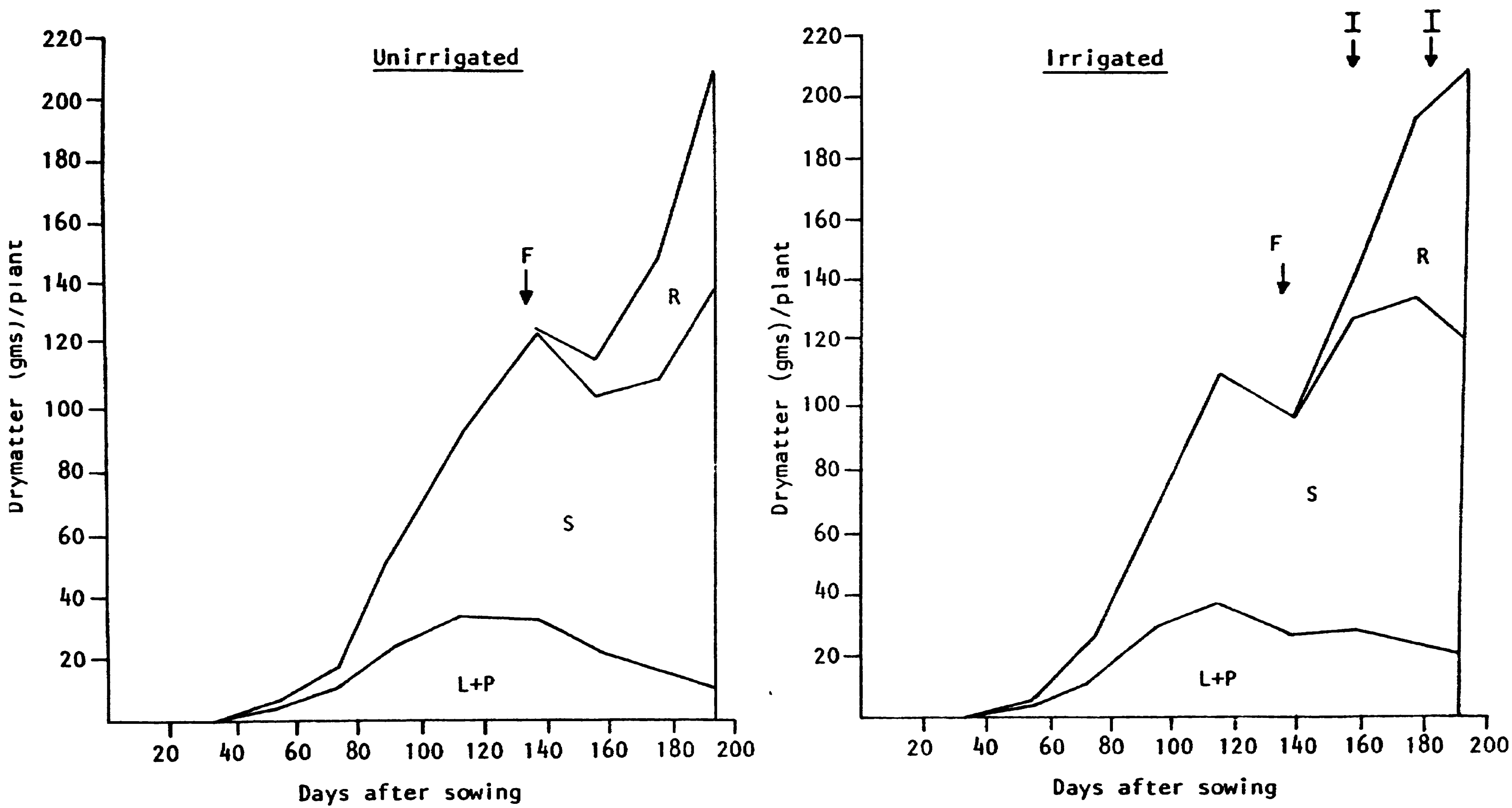


Figure 11. Distribution of dry matter throughout the growing season of pigeonpea (cv C-11) grown in the rainy season intercropped with sorghum. Dates of sorghum harvest (SH), flowering (F) and irrigation (I) are indicated by arrows. L+P = leaves + petioles, S = stem R = reproductive structures.

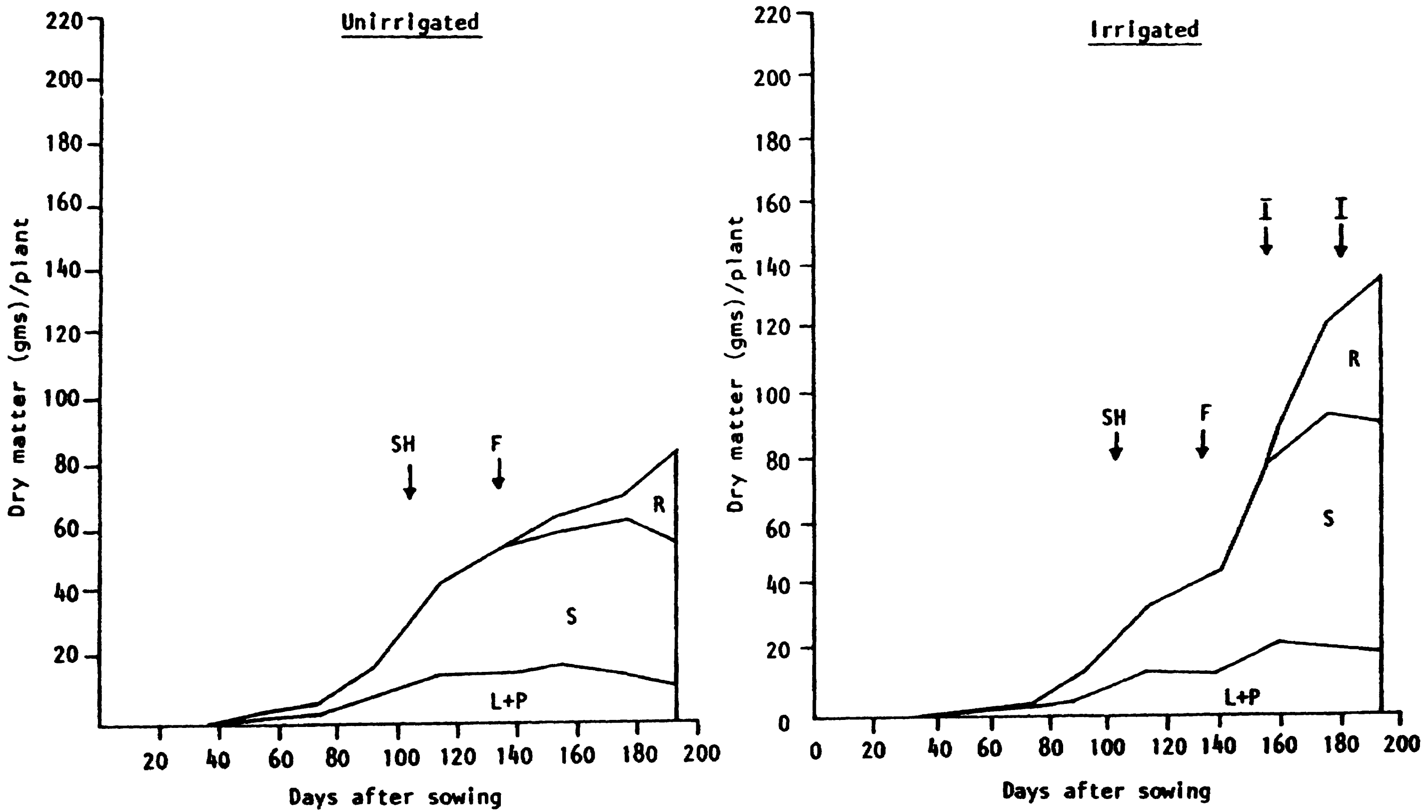
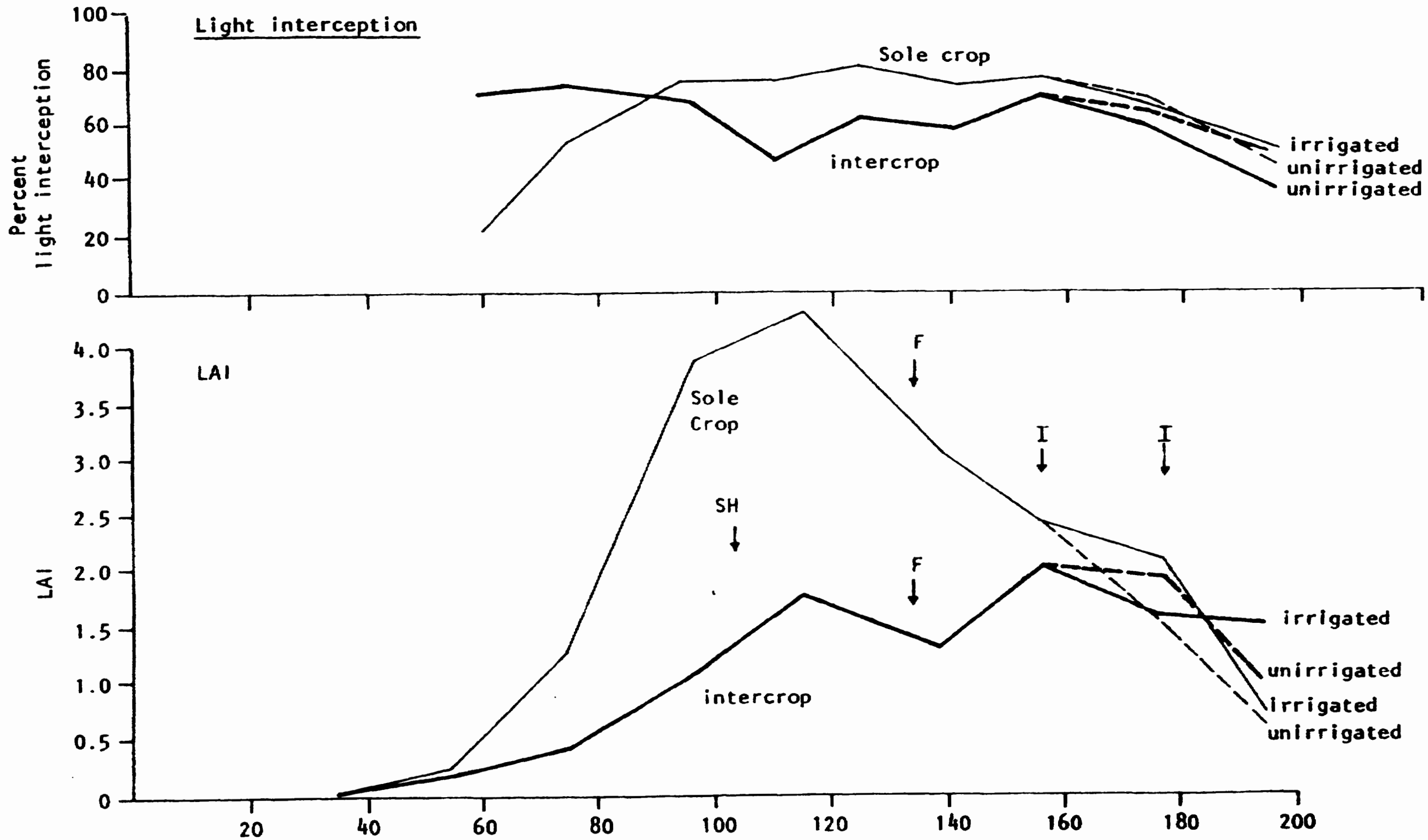


Figure 12. LAI and light interception by sole and intercropped pigeonpea (cv C-11) grown in the rainy season. Dates of sorghum harvest (SH), flowering (F) and irrigation (I) are indicated by arrows.



Light interception was greatest in the early stages in the intercrop, owing to the well-developed sorghum canopy, but of course fell when the sorghum was harvested. In the sole crop around the time of maximum LAI, light interception was 80%.

In the irrigated postrainy season crop, irrigation was given during the vegetative phase, and this resulted in considerably more growth than in the unirrigated controls (Fig. 13). With irrigation, the LAI continued to increase until the middle of the reproductive phase up to a maximum of 2.5, whereas the maximum LAI in the unirrigated plants was little more than 1, and the decline in leaf area began earlier. The maximum light interception in the irrigated plots was 74% and in the unirrigated 60%. Here, as in the case of the rainy season crop, light interception was not directly proportional to LAI. For example in the irrigated postrainy season crop, light interception fell after the 90th day, whereas LAI continued to rise for another 20 days or so (Fig. 14). In the rainy season sole crop, light interception at the 155th day was about the same as at the 95th day, but the LAI had declined from 4.0 to 2.5 (Fig. 12).

This lack of proportionality between LAI and light interception may be due to number of factors, including planting geometry, differences in the sun's position at the time of sampling, and pulvinar movements. The latter may be especially important in pigeonpea, since the approximate alignment of the leaflets with incident radiation, especially when the plants are under water stress, reduces light interception considerably (PPR 1974-75, pp. 73-77).

Harvest data

The mean total shoot dry matter produced by the sole-cropped pigeonpea was 65% higher than the intercropped pigeonpea, and nearly 3 times higher than the postrainy season crop (Table 38). In the rainy season crop, irrigation had little effect on the total shoot dry weight, probably because irrigation was given only towards the end of growing season. In the postrainy season crop, by contrast, irrigation led to a 76% increase in shoot dry weight, indicating that the growth of the plants was limited by the availability of water. This is what would be expected in the postrainy season, and confirms our previous findings.

The mean yield of the sole-cropped pigeonpeas was high, 2107 kg/ha. There was a 23% increase in response to irrigation (Table 39), indicating that in the unirrigated plants partitioning of dry matter into seeds was

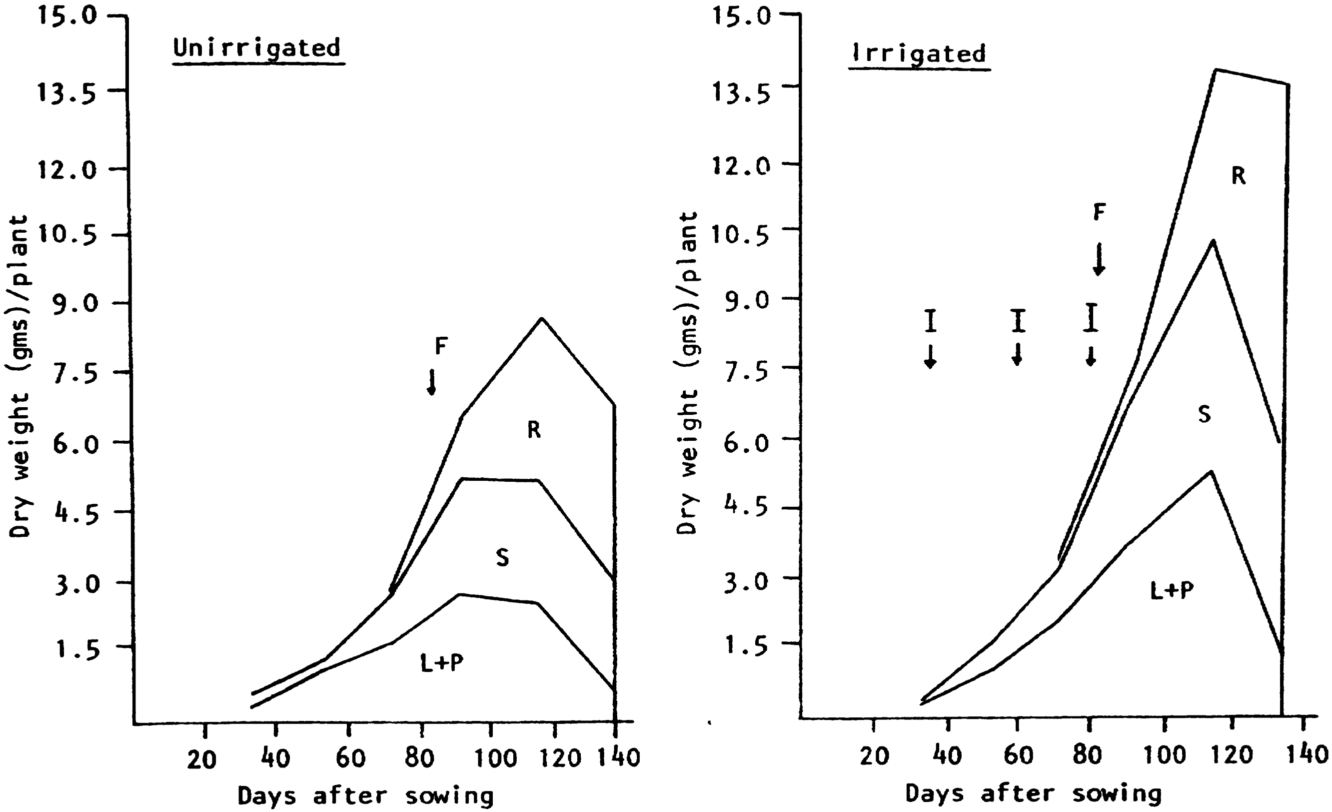


Figure 13. Distribution of dry matter throughout the growing season in pigeonpea (cv C-11) grown in the postrainy season. Dates of flowering (F) and irrigation (I) are indicated by arrows. L+P = leaves + petioles, S = stem , R = reproductive structures.

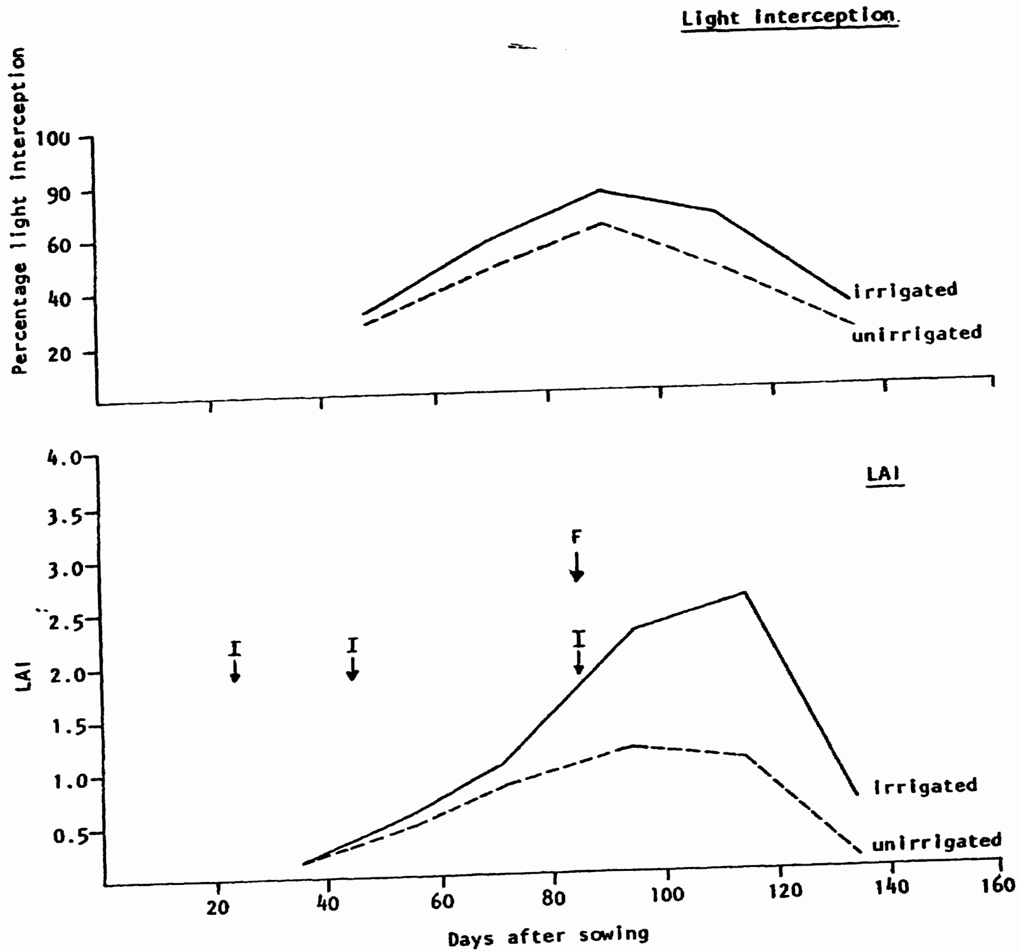


Figure 14. LAI and light interception by pigeonpea (cv C-11) grown in the postrainy season. Dates of flowering (F) and irrigation (I)are indicated by arrows.

Table 37. Dates of flowering and maturity of pigeonpeas grown in the rainy and postrainy seasons (Days after sowing are given in parentheses).

Crop	Date of 50% flowering		Date of maturity	
Sole (rainy season)	29.10.81	(133)	26.12.81	(192)
Intercrop (rainy season)	29.10.81	(133)	26.12.81	(192)
Postrainy season (unirrigated)	5.1.82	(83)	1.3.82	(138)
Postrainy season (irrigated)	5.1.82	(83)	5.3.82	(142)

Table 38. Effect of irrigation on the total shoot dry weight of pigeonpeas (cv. C-11) grown as a sole crop and intercropped with sorghum in the rainy season, and as a postrainy season crop.

	Total shoot dry weight (kg/ha)			
	Unirrigated		Irrigated	Mean
Sole crop	7784		8248	8016
Intercrop	4983		4790	4886
Rabi crop	2014		3550	2782
Mean	4927		5529	
SE		± 228		± 318

The standard error for comparing crops with in irrigations is ± 449 and for comparing irrigation with in crops ± 432.

Table 39. Effect of irrigation on the yield of pigeonpeas (cv. C-11) grown as a sole crop and intercropped with sorghum in the rainy season, and as a post-rainy season crop.

	Yield (kg/ha)		
	Unirrigated	Irrigated	Mean
Sole crop	1886	2328	2107
Intercrop	1432	1279	1356
Rabi crop	803	1088	946
Mean	1374	1565	
SE	± 46		± 93

Standard error for comparing crops with in irrigations is ± 131 and for comparing irrigations with in crops is ± 116.

limited to some extent by the availability of soil water. In the intercropped pigeonpeas, by contrast, irrigation had no beneficial effect. This could be because the rainfall in early October (Fig. 1), after the harvest of sorghum in late September, recharged the profile, and the amount present in the soil was adequate for the intercropped pigeonpeas which were much smaller than the sole cropped plants, with a lower LAI (Figs. 11 and 12), and would thus have required less water. This explanation can be checked directly when the data on the water content of the soil and water use by the crop become available. (We hope to include them in our next report). The sorghum intercrop yielded 5187 kg/ha.

In the postrainy season crop, the yield increase due to irrigation was only modest (35%). Larger increases have been observed in previous years (eg. PPR 1980-81, Section VIII). One reason for the difference may be that this year the irrigations were given only up to the time of flowering. None were given in the reproductive phase, when the crop would have been subject to increasing water stress, and also suffering from root damage due to soil cracking.

The mean yield per plant in the sole crop was 42.7 g, in the intercrop 35.3 g, and in the rabi crop only 3.2 g, reflecting the much smaller plant size in the postrainy season. The mean harvest indices were 26, 28 and 35% respectively. Interestingly, in the case of the rabi crop the harvest index was reduced by irrigation from 39 to 31% (significant at the 5% level). In previous years, irrigation has tended to increase harvest index in cv. C-11, but this has not always been the case with other cultivars. Last year, for example in October-sown cv. NP(WR)-15 HI was reduced by irrigation (PPR 1980-81, Table 25). Irrigation would reduce HI if it favoured vegetative growth more than partitioning of dry matter into reproductive structures. In cv. C-11 this year, this may have happened because irrigation was supplied only up to the time of flowering, and not during the reproductive phase.

Irrigation had no significant effect either on seed number per pod or 100-seed weight in any of the three cropping systems. However, there was a tendency for the rabi crop to have fewer seeds per pod (2.6) than the sole crop (3.0); there were also fewer in the intercropped plants (2.7). The 100-seed weight was significantly lower in the rabi crop (7.7 g) than in the sole crop (9.8 g) and intercrop (9.2 g) (LSD (5%) = 1.4).

XIII. PRELIMINARY OBSERVATIONS ON SHOOT WATER POTENTIAL OF PIGEONPEAS

The response to irrigation in both kharif-sown (Section XII this report) and rabi pigeonpeas (PPR 1979-80, Section VIII, 1980-81, Section VIII) suggests that water is a limiting factor in the postrainy season.

As a part of standardization of technique to gain information on this aspect we carried out measurement of water potential of pigeonpea using a PMS Pressure Chamber at different times of the day. The measurements were made on kharif sown and rabi crops. The fields and the date of measurements are given below:

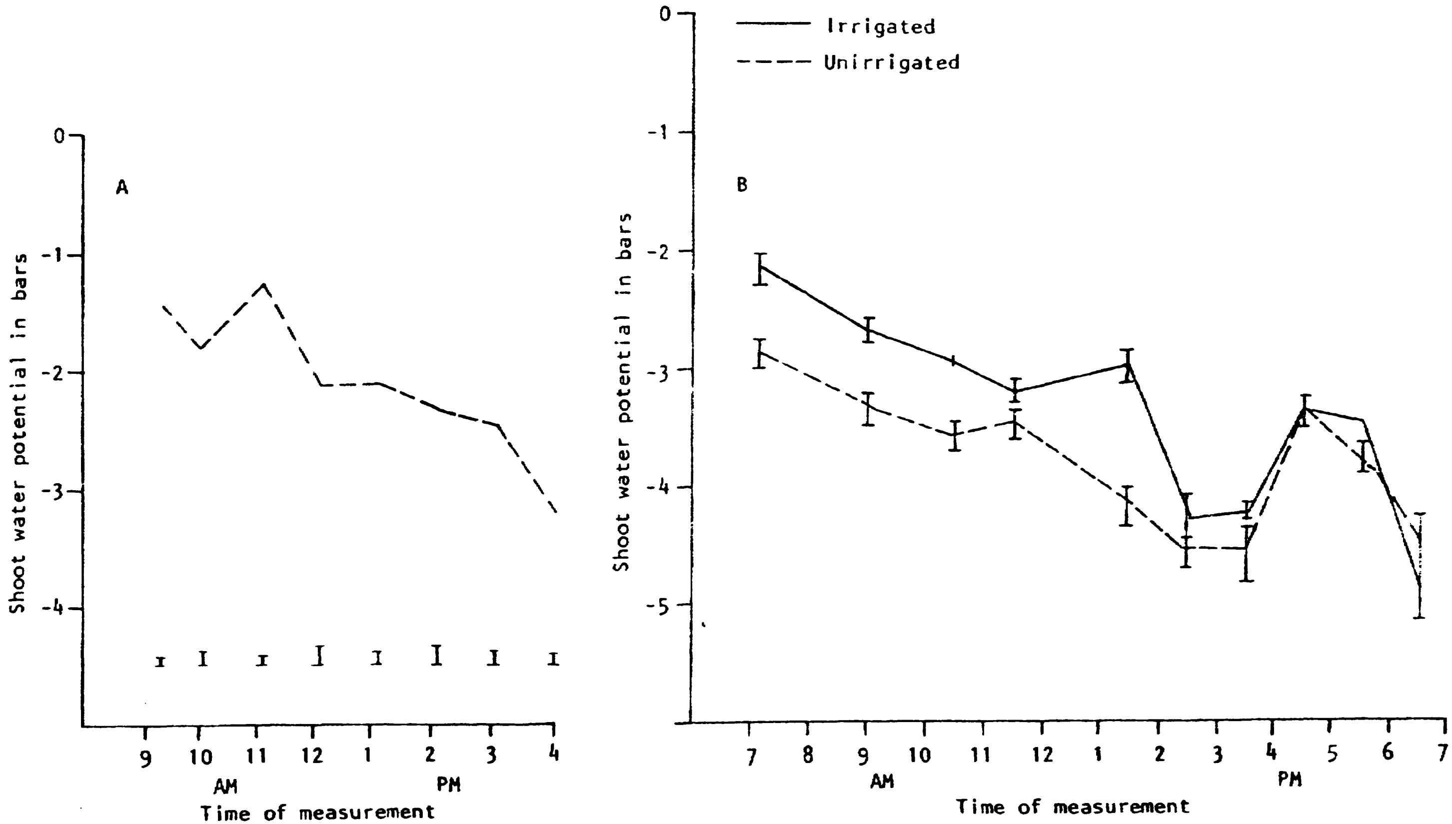
Crop field	sowing date	treatment	date of last irrigation	date of shoot water potential measurement
Kharif BW-5	19.6.81	unirrigated	-	11.12.81
Rabi BW-3	14.10.81	unirrigated & irrigated	19.1.82	5.2.82

For measurement of water potential a shoot tip bearing 5 leaves was excised using a stainless steel blade and brought quickly for measurements with a pressure chamber which was kept nearby in the field. The shoot was sealed into the chamber, through a split rubber bung, with the cut end protruding outwards. The gas pressure inside the pressure chamber was increased at a constant rate from the nitrogen cylinder until the xylem sap between the exude from the cut surface, signifying an equivalence between the pressure in the chamber and in the shoot tissue. This was read from the pressure guage.

The water potentials of shoots from kharif-sown pigeonpeas at different times of day are given in Fig. 15. They indicate that water potential in the morning hours was around -1.5 bars and decreased to -3.2 bars by 4.00 p.m.

Similarly in rabi pigeonpeas, the water deficit was not very low even in unirrigated plants. The lowest water potential of -4.9 was recorded between 6 and 7 p.m. Both irrigated and unirrigated pigeonpeas showed a nearly identical pattern of change in water potential although both showed consistant differences in shoot water potential until 3.30 p.m., with a higher potential in the irrigated plants. The shoot water potential decreased again after a brief increase between 4.30 p.m. and 5.30 p.m.

Figure 15. Water potential of shoots of pigeonpea (cv C-11) at different times of the day in A, kharif crop on Dec 11, 1981, B. Rabi crop on Feb5,1982. (The values represent mean of 5 individual measurements).



These preliminary results have two main features of interest. First, the shoot water potentials remained remarkably high, even under conditions in which water stress would have been expected. In chickpeas at ICRISAT Center, for example, shoot water potentials of in the range of -12 to -18 bars are found around 2 p.m. even in irrigated plants (CPR 1978-79, Figs. 27 and 28; CPR 1979-80, Fig. 4). Secondly, in chickpea and various other crops, the shoot water potential usually reaches a minimum around or soon after midday, and then recovers (CPR 1978-79, Figs. 27 and 28) as a result of stomatal closure. But we found no such pattern in pigeonpea, where the water potential continued to decline throughout the day.

From Figs. 16 and 17 it appears that stomatal conductance and transpiration rates measured with the help of steady state porometer in postrainy season sown pigeonpea were similar in irrigated and unirrigated plants and as such do not provide any clue as to why the crop was able to maintain high water potential even under unirrigated conditions. Under such condition it may be logical to assume that roots have fairly high rates of absorption of water to meet the transpiration demand. However, we do not know if in unirrigated plants there is a more extensive development of the root system than in irrigated plants, but this possibility can be checked in studies carried out in large plastic pots from which the root system could be quantitatively extracted.

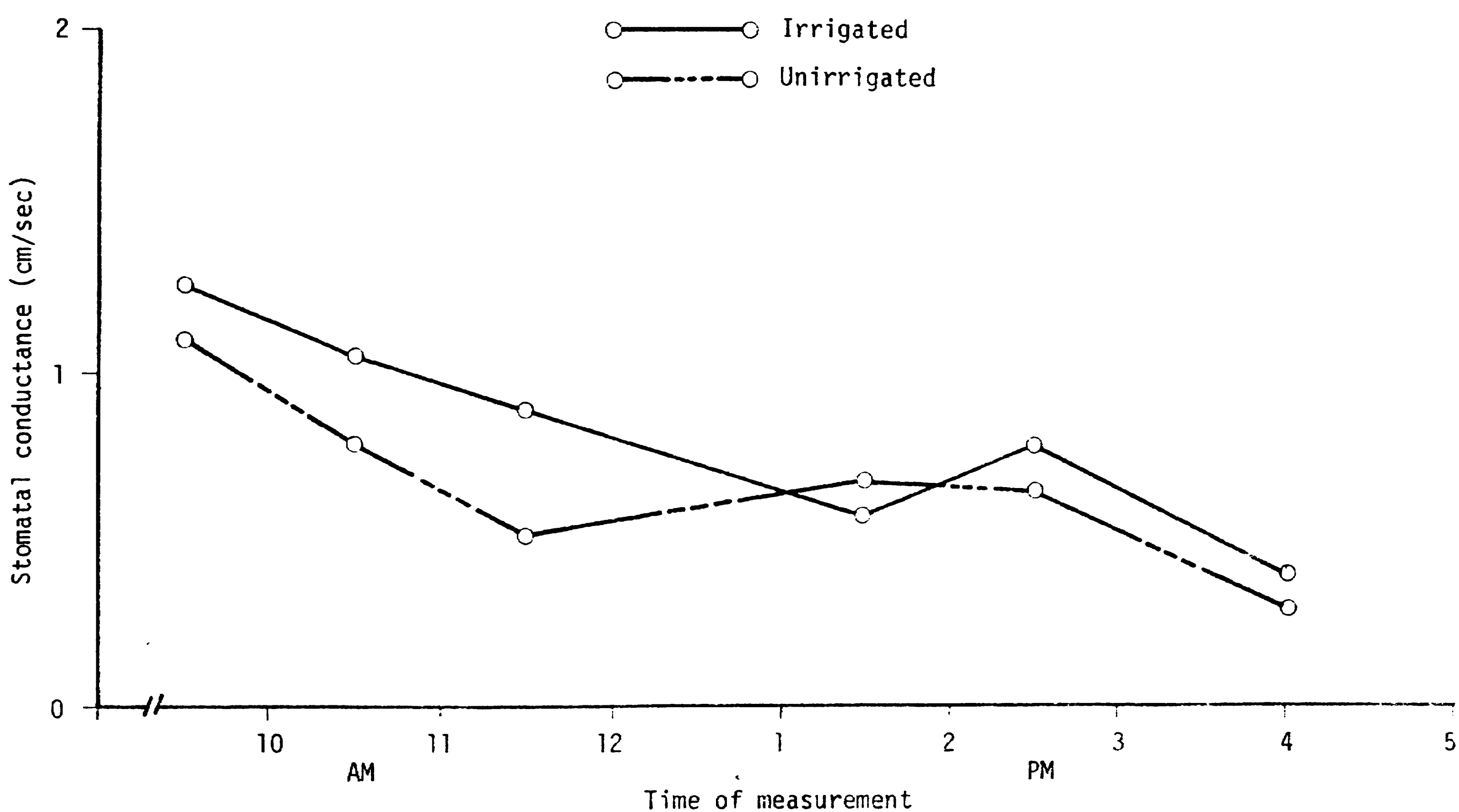


Figure 16. Time vs. stomatal conductance (cm/sec) in irrigated and unirrigated rabi pigeonpea.

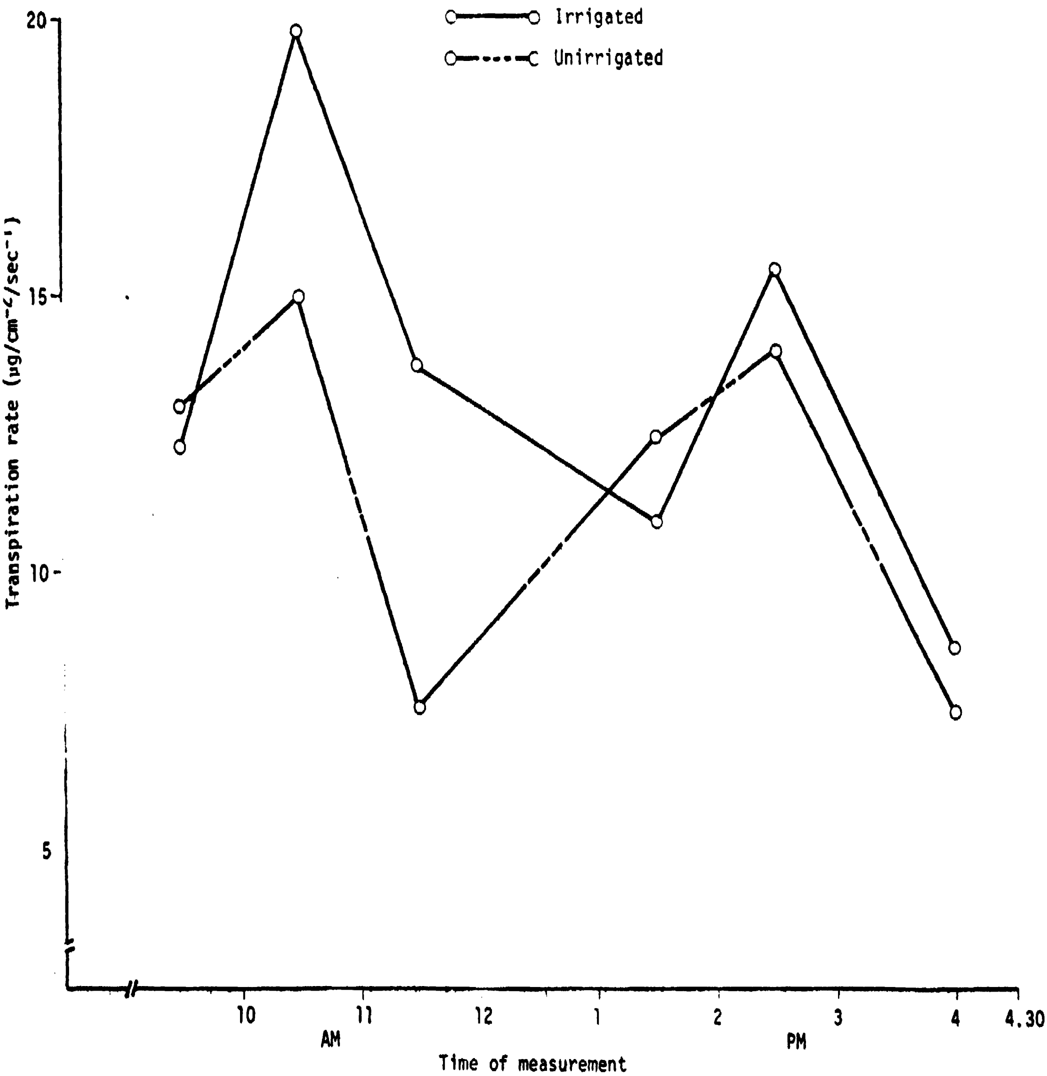


Figure 17. Time vs. transpiration rate (μg/cm^2/sec) in irrigated and unirrigated rabi pigeonpea.

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