MR. D. J. Andrew

PULSE PHYSIOLOGY
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Part I

PIGEONPEA PHYSIOLOGY

By

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PIGEONPEA PHYSIOLOGY

STAFF 1976/7

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ABBREVIATIONS AND DEFINITIONS

HI = Harvest Index $= \frac{\text{Grain Dry Weight}}{\text{Total Plant Dry Weight at Harvest}} \times 100$

LAI = Leaf Area Index $= \frac{\text{Total Leaf Area of Crop}}{\text{Ground Area Occupied by Crop}}$

LAD = Leaf Area Duration = Sum of Weekly Average LAI throughout the Growing Season

CGR = Crop Growth Rate = Dry Weight gained by Unit Area of Crop in Unit Time.

SLW = Specific Leaf Weight $= \frac{\text{Leaf Dry Weight}}{\text{Leaf Area}}$

Notes: 1. At Hyderabad the kharif or monsoon season lasts from June until October and the rabi or winter season from October to March.

2. The ICRISAT numbers of cultivars are now proceeded by the acronym ICP, standing for ICRISAT pigeonpea. Thus, for example, cv. ICRISAT-1 is now referred to as cv. ICP-1.

CONTENTS

S U M M A R Y

I. ANALYSIS OF GROWTH AND YIELD:

1. The effects of nitrogenous fertilizer and farm yard manure on growth, nodulation, nutrient uptake and yield of a medium-duration cultivar were investigated on black and red soil. The nitrogenous fertilizer resulted in faster growth rates in the early stages of growth, but neither the fertilizer nor farm yard manure had any significant effect on yield. The nitrogenous fertilizer had relatively little effect in inhibiting nodulation or nitrogenase activity. Fertilization with 200 kg/ha nitrogen resulted in an increased nitrogen uptake of only 42 kg/ha on black soil and 16 kg/ha on red soil. These nitrogen-fertilized plants had more nitrogen in the stems and fallen leaves than controls, but not in the grain. In control plants about 30 kg/ha of nitrogen was returned to the soil in fallen leaves. There was a considerable remobilization of nitrogen and phosphorus from leaves during their senescence.

2. The shoot/root ratios of plants at the time of harvest were determined using plants grown in large brick chambers from which the roots could be more or less completely recovered. The shoot/root ratio was 4 in black soil and 3.5 in red soil.

II. EXPERIMENTAL INVESTIGATIONS ON SOURCE-SINK RELATIONSHIPS:

1. Mechanical stimulation of the plants during the reproductive phase had no significant effect on yield or yield components.

2. Removal of all flowers and young pods for up to 5-7 weeks had little or no significant effect on final yield.

3. Removal of flowers from different parts of the plants resulted in compensatory pod-set in other parts of the plants.

4. The removal of half the number of leaves on the plants throughout the reproductive phase had only a slight and statistically insignificant effect on yield, and also had no significant effect on seed number per pod or 100-seed weight. Yield was significantly reduced by total defoliation and the 100-seed weights were significantly affected by this treatment.

5. In cv. ICP-1 total defoliation carried out 5 weeks after flowering began had no significant effect on yield or yield components. Total defoliation 3 weeks after flowering began resulted in a reduced pod number per plant and reduced 100-seed weight but had no effect on seed number per pod.

6. The defoliation of alternate branches throughout the reproductive period resulted in a slightly lower yield than the defoliation of alternate nodes within branches, but the differences were not significant at the 5% level.

7. The removal of senescent leaves throughout the reproductive phase had no effect on yield or yield components.

8. The removal of apical buds from the main stem and branches at the beginning of the reproductive phase had no effects on yield or harvest index.

9. Shading throughout the reproductive phase of pigeonpeas grown as a rabi crop led to significant reductions in yield.

III. CULTIVARAL CHARACTERISTICS AND CULTIVARAL DIFFERENCES:

1. The response of different cultivars to row spacing in 'fan' plantings was investigated in the kharif and rabi seasons. There were marked differences between cultivars in their ability to yield well over a wide range of spacings; the upright sparsely-branching cultivar HY-3A was markedly less plastic than more branching spreading types. Row spacing had little or no effect on seed number per pod or 100-seed weight but harvest index changed considerably.

2. In some cultivars defoliation during the vegetative phase had little effect on final yield but in other cultivars the yield was significantly reduced. Defoliation at the beginning of the reproductive phase tended to increase the incidence of the wilt disease, especially in cv. HY-3C.

3. Within the racemes of a range of cultivars there was little or no difference between the pod weight, seed weight and seed number per pod in the earlier-formed pods at the basal nodes of the raceme and the later-formed pods at the apical nodes.

4. In a range of cultivars there was little or no difference between the pod weights, seed weights or seed number per pod in the pods from the racemes at the basal and apical parts of the branches.

5. Significant cultivaral differences were found in the specific leaf weight and the decline in specific leaf weight and nitrogen content during senescence, but there was no significant correlation between these variables in the same cultivars grown on black and red soils.

6. Significant cultivaral differences were detected in the ability of seeds to germinate under alkaline and saline conditions in the

laboratory. There was no correlation between cultivaral performance under the two sets of conditions.

7. No significant differences were found between the ovule numbers in flowers formed towards the beginning and the end of the reproductive phase.

8. Heritable differences in seed size within cultivars were found, indicating the genetic heterogeneity of these cultivars.

IV. EFFECTS OF CULTURAL CONDITIONS AND CULTURAL PRACTICES ON GROWTH AND YIELD:

1. Pigeonpeas grown after pigeonpeas showed reduced growth and yield but other crops tested were relatively unaffected. The effect of pigeonpeas on subsequent crops of pigeonpeas was not brought about by pigeonpea residues.

2. The best second-harvest yields were obtained from plants which were not ratooned at the time of the first harvest. Ratooning resulted in a delay in the second flush of flowering; ratooning lower down resulted in longer delays, and greater reductions in second-harvest yields.

3. Second-year yields were reduced by the sterility mosaic disease and the wilt disease. Promising results were obtained in the kharif season with pigeonpeas which had already produced a crop in the previous rabi season.

4. Excellent yields were obtained from pigeonpeas grown as a rabi crop. The best cultivar, C-11, yielded 1700 kg/ha. The highest yields were obtained with a population of 12.5 plants/m^2. The harvest index of the rabi crop was higher than in the kharif crop; the 100-seed weights were lower but the milling-recovery and the palatibility of the seed were normal.

INTRODUCTION

In this report we present results of work carried out between June 1976 and May 1977.

The meteorological data for 1976/7 collected at the ICRISAT Agroclimatological observatory are shown in Fig.1. The dates of sowing, flowering and harvest of the kharif and rabi pigeonpea are indicated in the figures. The most striking feature of the weather for this year was unusually early cessation of the monsoon resulting in very little rainfall in September. There was a cyclonic storm in the month of November.

Seeds were sown for the kharif experiments between 25-6-76 and 8-7-76. Fertilizers were broadcast at the rate of 50 kg P_2O_5 and 22 kg $ZnSO_4$/ha and incorporated before the fields were flattened or ridged. The early cvs were sown in flat seed beds with 50 cms between rows and 30 cms plant to plant. The medium and late cvs were sown on ridges (75 cm between ridges and 30 cm plant to plant). Two seeds per hill were sown by hand; 2-3 weeks after germination the seedlings were thinned to one per hill.

The soils were analysed at the time of harvest for pH, electrical conductivity and available nitrogen. The results are shown in Table 1.

Hand weeding was carried out frequently to keep the plots as weed-free as possible. Periodic insecticidal sprays (endosulphan) and other plant protection measures (such as the removal of blister beetles by hand) were carried out with the cooperation of the ICRISAT Plant Protection Unit.

In the red soil precision field R1 there was considerable seedling mortality owing to an attack of *Sclerotium rolfsii*. The fungus had multiplied on sorghum straw which had been ploughed into the soil. Later, in the same field, a number of plots were badly damaged by poor drainage and flooding. There was also a bad attack of *Phytophthora* stem blight which killed many plants of some cultivars while other cultivars remained almost unaffected. Apart from these calamities, plant growth was normal in all other trials. Yields were, however, generally lower this year than in the preceding years probably because of moisture stress resulting from the early cessation of the monsoon.

We have referred to our Pigeonpea Physiology Reports for 1974/5 and 1975/6 as PPR 1974/5 and PPR 1975/6. We have also referred to the Chickpea Physiology Reports (CPR) for these years. Copies of the 1975/6 reports can be supplied on request.

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

Table 1. Soil analysis

Soil and field No.	Depth of soil (cm)	pH*	EC*	Available N (ppm)
Black (vertisol) Field (ST-1)	0 - 30	8.15	0.20	65.8
	30 - 60	8.20	0.67	67.2
	60 - 90	8.55	0.35	54.2
	90 -120	8.60	0.55	53.2
	120 -150	8.72	0.65	51.8
Black (vertisol) Field (B-5)	0 - 15	8.20	0.10	60.2
	15 - 30	8.10	0.10	54.6
Red (alfisol) Field R-1	0 - 15	7.80	0.15	67.2
	15 - 30	7.75	0.21	61.6

* in 1:2 soil extract

FIG. 1 METEOROLOGICAL DATA (JUNE 1976-APRIL 1977)

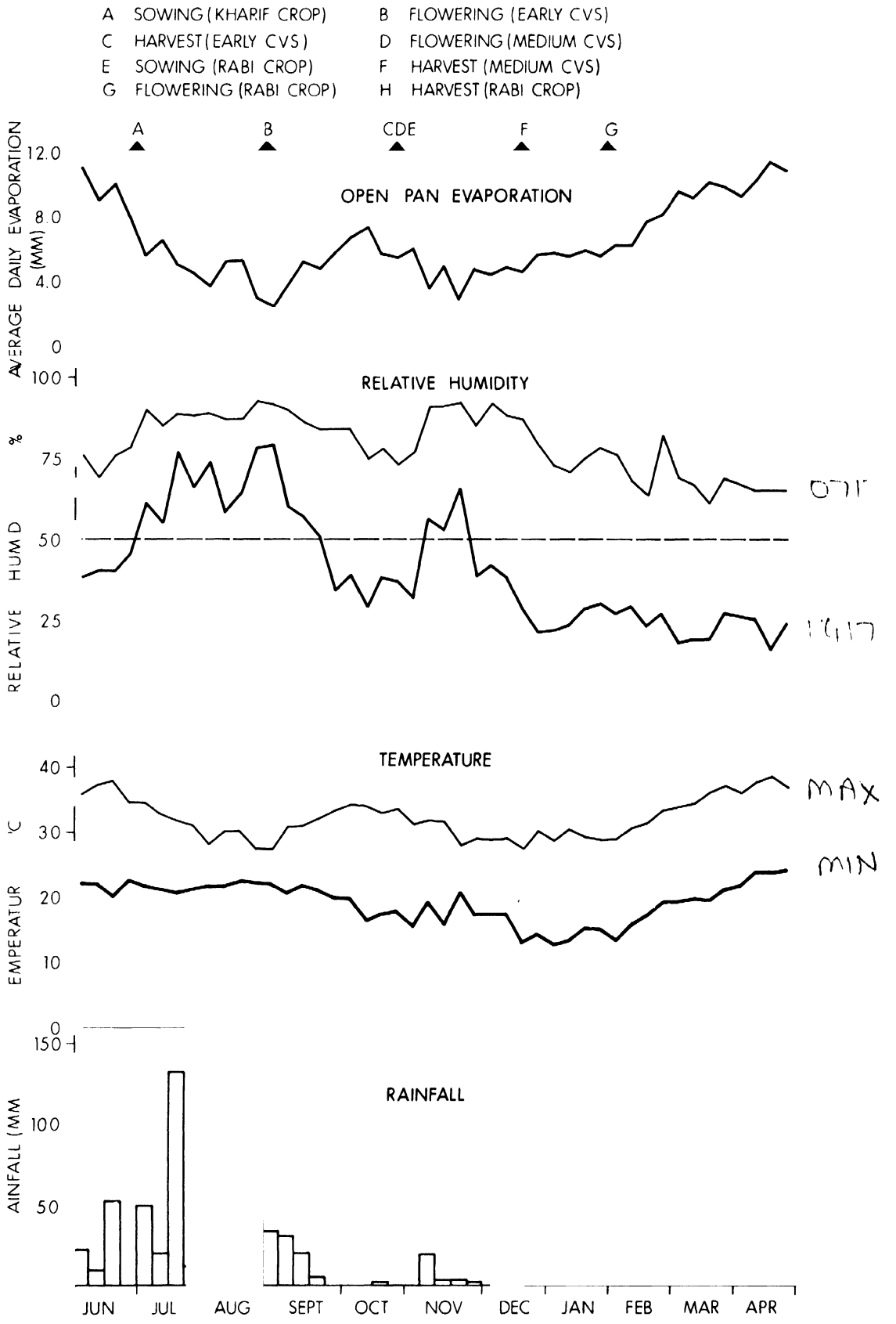
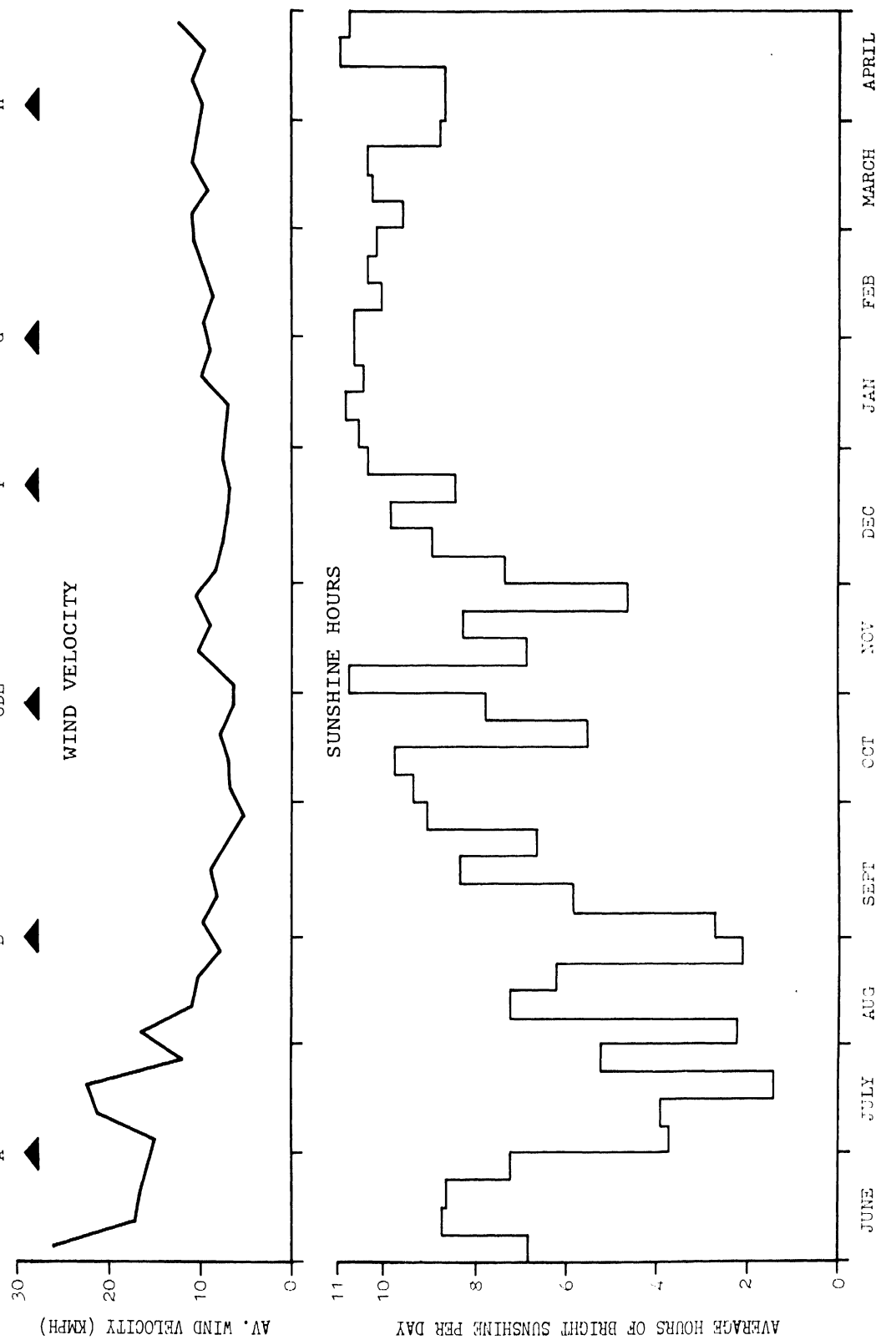


FIGURE 1. METEOROLOGICAL DATA (Continued)



I.1.

EFFECT OF NITROGEN FERTILIZER AND FARM YARD MANURE ON THE GROWTH YIELD AND NUTRIENT UPTAKE OF PIGEONPEA

In improved cereal-pigeonpea inter-cropping systems, there is a need to apply nitrogenous fertilizer to the cereal crop. However it is probably not possible to confine this fertilizer to the cereal alone, even if it is banded in the cereal rows. We found last year in an investigation of sorghum-pigeonpea intercrops that the pigeonpea roots spread under the sorghum rows, and that the pigeonpeas responded in growth, but not significantly in yield, to the nitrogenous fertilizer applied to the sorghum (see PPR 1975/6 Section 1.4). This year we carried out an experiment in collaboration with the Microbiology Section to study the effects of nitrogenous fertilization and farm yard manure on the nodulation, growth and yield of pigeonpeas grown as a sole crop on both black and red soils. The nodules were sampled at regular intervals and their nitrogenase activity was measured by the Microbiology Section; results of these measurements will be presented in detail in the ICRISAT Microbiology report.

Materials and Methods

Cultivar ICRISAT-1 (ICP-1: medium duration) was used in this trial. The land was fertilized with single superphosphate (50 kg P_2O_5/ha) and zinc sulphate (22 kg/ha) before sowing. The treatments were: no nitrogen fertilizer (control); 20 kg/ha N; 200 kg/ha N; and farm yard manure (FYM) at the rate of 20 tons/ha. The nitrogen fertilizer was calcium ammonium nitrate (CAN, 26% N). The nitrogenous fertilizer and farm yard manure were broadcast and incorporated into the soil before sowing. The four treatments were carried out in a randomized block design with four replications. The plot size was 7x9 M, with row to row spacing of 75 cm with 30 cm plant to plant spacing within rows. In the red soil planting was done on ridges; in the black soil the seed bed was flat. The dates of sowing were 29-6-76 on black soil and 3-7-76 on red soil.

Destructive growth analysis was carried out at monthly intervals. Five plants per plot were sampled on each occasion, and roots and nodules were extracted by Dr. Kumar Rao of the Microbiology Section for nitrogenase assays. In the N_0 and N_{200} treatments a $9m^2$ sub-plot within each replicate plot was marked out and from these sub-plots all the fallen leaves, flowers and pods were collected at weekly intervals.

Total shoot dry weight, yield and yield components were recorded at the time of harvest (20-12-76 on black soil; 10-12-76 on red soil). The fallen leaves etc. within each plot were also collected and weighed.

The dried samples from the growth analysis of N_0 and N_{200} treatments were ground to powder and analysed for nitrogen by the Kjeldahl method and for phosphorus (N_0 samples only) in the Central Analytical Laboratory by Mr. G. Ravi Kumar under the direction of Dr. R. Jambunathan. Samples from replicates 1 and 3 were pooled for analysis and samples from the other replicates were kept in reserve for use if the other samples were lost or for checking on any anomalous results. The entire stem system was ground for the stem samples but for the last two sampling dates the stem of only one plant per replicate was ground.

Results

A. Morphological Observations

(a) Height:

The plants grew taller on black soil than on red soil. On the black soil during the early stages of growth the plants supplied with nitrogen or farm-yard manure grew taller than the controls; in red soil the growth-stimulating effect of the N_{200} treatment was pronounced. On both soils the height of the N_{200}-treated plants was slightly greater even at the time of harvest (Table 2).

(b) Leaf number and Leaf scars:

The N_{200} treatment resulted in an increased number of leaves per plant within thirty days of planting on both soils, and also resulted in a greater total number of leaves being retained at the time of harvest (Table 2). The number of leaves which had fallen was indicated by the number of leaf scars; it can be seen from Table 2 that the plants fertilized with N_{200} had also lost more leaves than the other plants and produced a greater total number of nodes.

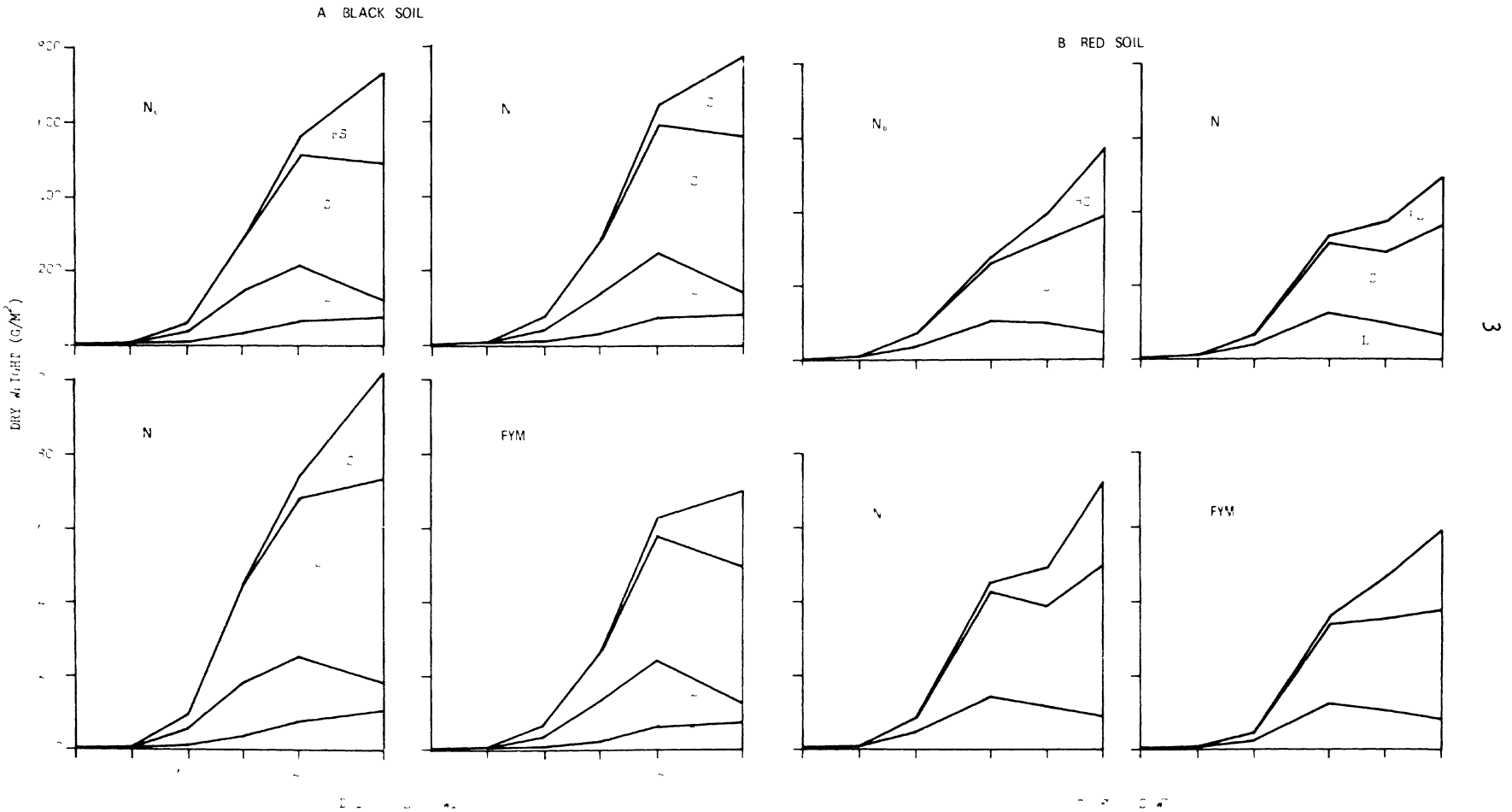
B. Growth Analysis

(a) Dry matter production:

At first the growth on black and red soils was comparable, but after about 60 days growth on black soil was better than on red. On both soils N_{200} had a stimulatory effect from 30 days onwards; on black soil N_{20} and FYM did not result in increased dry matter compared with unfertilized controls after 60 days; on red soil ~~than~~ treatments had little or no detectable effect (Fig. 2).

FIGURE 2 DISTRIBUTION OF DRY MATTER THROUGHOUT THE GROWING SEASON IN CV ICP-1 GROWN ON RED AND BLACK SOILS AFTER NO FERTILIZATION AND FERTILIZATION WITH 20 AND 200 Kg/ha NITROGEN AND FARM YARD MANURE

RS REPRODUCTIVE STRUCTURES
S STEMS
L LEAVES (Including Petioles)
R ROOTS



The shoot/root ratio increased during the first 90 days of growth in all the treatments (Table 3). However only the superficial roots were extracted for weighing; as time went on more root growth would have taken place in the deeper zones of the soil (see PPR 1974/5 Chapter II; PPR 1975/6 Section I.4). Hence the method we used would probably have resulted in a progressive underestimation of root weight, and consequently an overestimation of the shoot/root ratio.

On both soils the N_{200} treatment resulted in increased stem growth and a higher stem dry weight at the time of harvest. The relative proportion of dry weight in the branches may also have been increased slightly by this treatment (Table 4).

(b) Leaf Area Index:

On both soils the N_{200} treatment led to an increased LAI from 60 days onwards (Fig. 3). The LAIs achieved on black soil were higher than those on red soil and were maintained for longer; the LAI began declining sooner on the red soil, probably because of moisture stress which developed during the reproductive phase. As a result of these differences in LAI the leaf area durations were greater on black soil than on red; on both soils they were increased by N_{200} treatments (Table 5).

(c) Crop Growth Rate:

On both soils the N_{200} treatments had the highest CGRs until about 75 days after sowing; during the next month, however, the CGRs of the other treatments exceeded them (Fig. 4). This may have been because the N_{200} treated plants achieved a higher LAI sooner (Fig.3) and may therefore have more rapidly been affected by mutual shading within the canopy.

The CGRs on red soil were initially higher than those on black soil but were lower after the first month and declined sooner, probably because the plants experienced more moisture stress. The rise in CGRs towards the end of the reproductive phase on red soil may have been owing to the rainfall which took place in November, around the 125th day after sowing.

(d) Fallen Plant Material:

The cumulative dry weights of the fallen leaves, flowers and pods at weekly intervals for the N_0 and N_{200} treatments on black soil are shown in Fig.5. Leaf fall, which was greater in the N_{200} treatment occurred at a fairly constant rate up to about 128 days after sowing; from 135 days onwards the rate was lower. A slightly greater weight of buds and flowers fell from the N_0 plants whereas a slightly greater

Table 2. Morphological characters of cv. ICP-1 at the time of harvest.

Treatments	A Height cm.		B No.leaves/plant		C No. of leaf scars/plant		D No. of nodes/ plant (B+C)	
	Black soil	Red soil	Black soil	Red soil	Black soil	Red soil	Black soil	Red soil
N_0	155	138	143	159	268	148	411	307
N_{20}	167	136	177	153	311	149	488	301
N_{200}	172	142	200	194	308	165	508	359
FYM	163	139	161	160	257	134	418	304

Table 3. Shoot/root ratio of cv. ICP-1 throughout the growth period on black soil.

SHOOT/ROOT RATIO

Treatments	DAYS FROM SOWING				
	30	60	90	120	165
N_0	4.0	5.6	9.0	8.5	8.4
N_{20}	4.4	6.1	8.9	7.8	8.2
N_{200}	4.4	5.8	10.5	8.0	8.1
FYM	4.3	6.6	8.9	8.5	8.6

Table 4. Total dry weight of stems at the time of harvest and the percentage of the stem dry weight present in the branches.

Treatments	Total stem dry weight (g/m^2)		Percentage of stem dry weight in branches	
	Black soil	Red soil	Black soil	Red soil
N_0	376	313	66.6	59.7
N_{20}	415	293	64.2	60.3
N_{200}	545	406	67.1	65.0
FYM	369	297	63.5	54.5

Table 5. Leaf area duration of cv. ICP-1 grown on black and red soils.

Treatments	Leaf area duration (weeks)	
	Black soil	Red soil
N_0	25.7	21.4
N_{20}	29.3	21.6
N_{200}	34.9	27.9
FYM	28.2	23.4

FIGURE 3: LEAF AREA INDEX OF CV ICP-1 THROUGHOUT THE GROWING SEASON

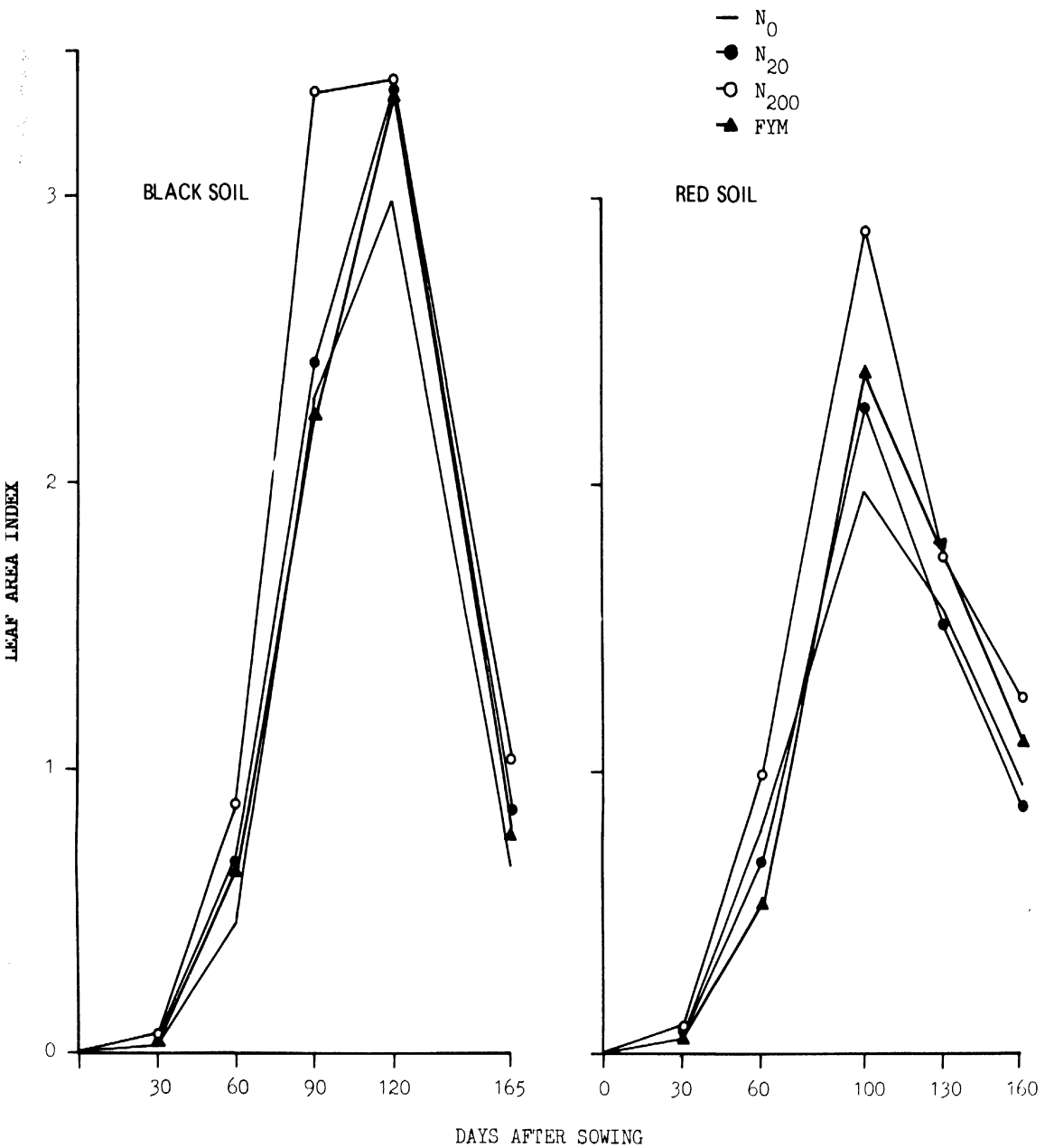


FIG. 4 : CROP GROWTH RATE OF cv ICP-1 ON BLACK AND RED SOILS

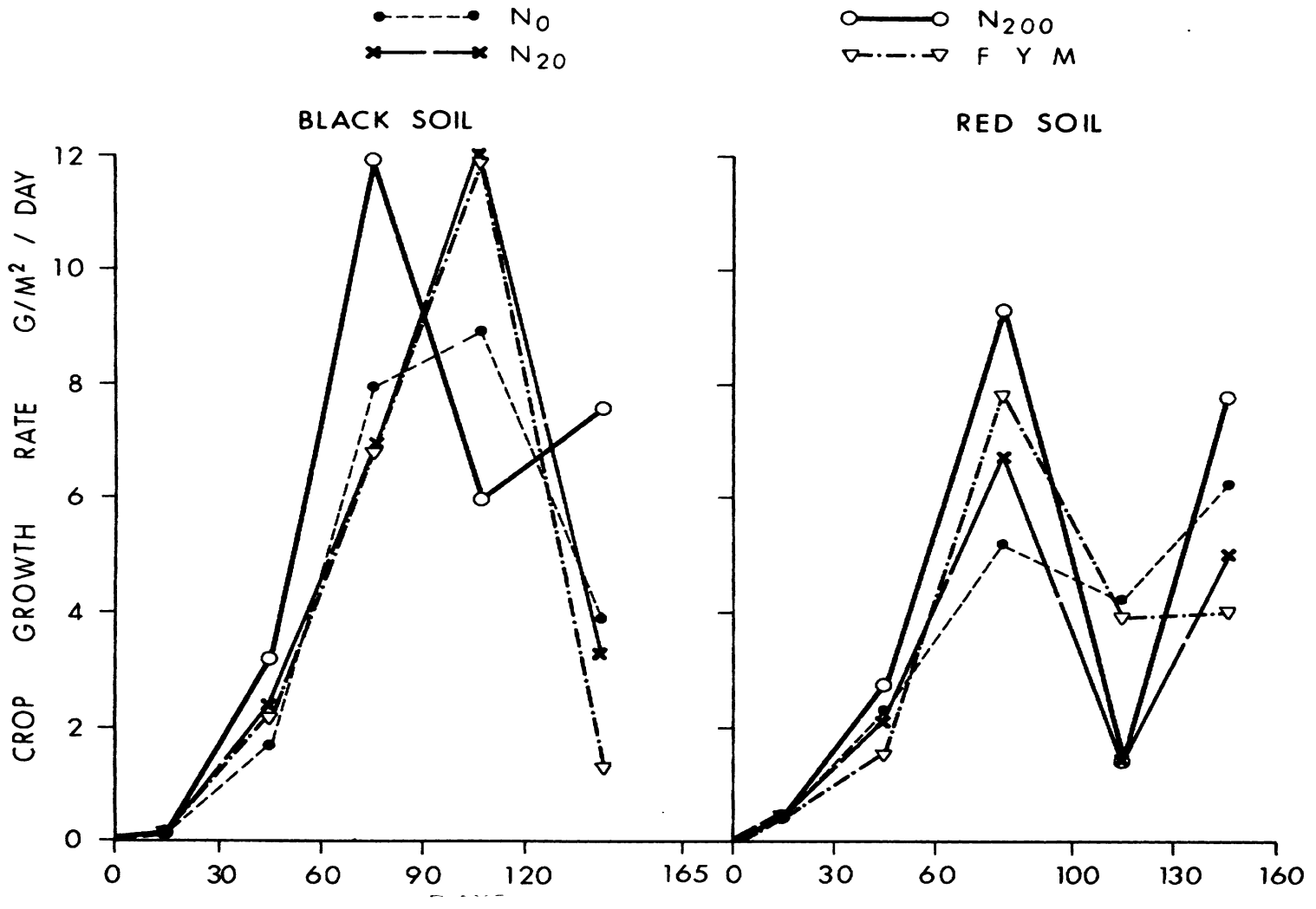
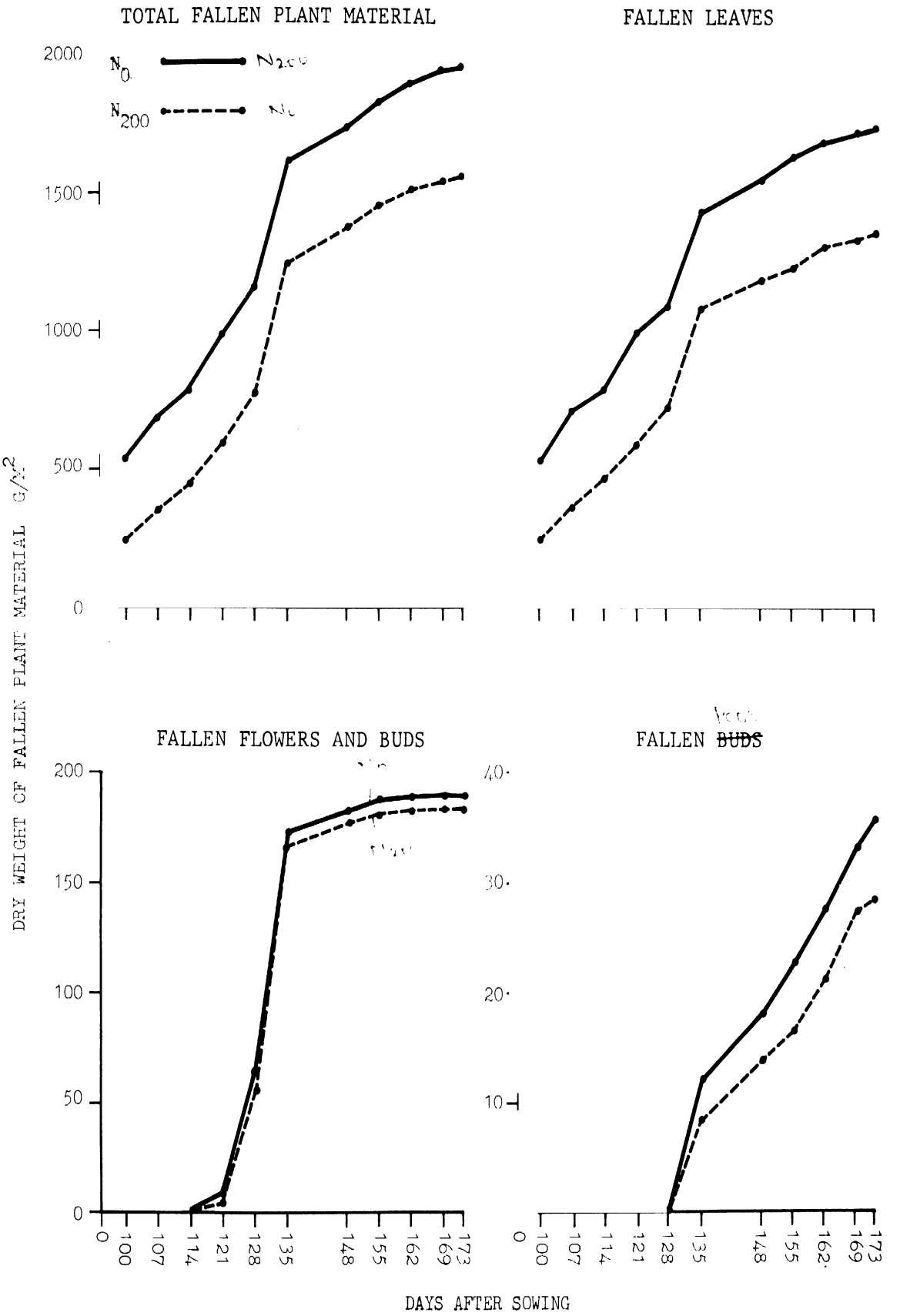


FIGURE 5. CUMULATIVE WEIGHT OF FALLEN PLANT MATERIAL OF CV ICP-1 GROWN IN BLACK SOIL AT TWO LEVELS OF NITROGEN.



weight of pods fell from the N_{200}-treated plants. This might indicate that there was more pod set on the N_{200} plants, and also that more pods dropped off, mostly at an early stage.

There was a cyclonic storm 130 days after sowing in the early reproductive phase. The rate of leaf fall increased at this time, and there was also a considerable amount of bud and flower drop. However the rate of bud and flower drop was even higher in the following week and it is more likely that this reflects the peak flowering period of the plants rather than the effects of the weather.

The total weights of the fallen plant material at the time of harvest are shown in Table 6. The leaves made up 86-89% of the total.

C. Yield

The yield data from the plot harvests are shown in Table 7. On neither soil did the fertilization treatments have any significant effect on yield.

On the red soil the growth was patchy and variable resulting in a high coefficient of variation for the harvest data, none of which were significantly different as a result of the nitrogen treatments.

On the black soil the plants fertilized with nitrogen produced a significantly greater total shoot weight and more fallen leaves than the unfertilized controls (Table 7); because the yields were almost the same, the nitrogen-fertilized plants had lower harvest indices than the controls, though the differences were not significant at the 5% level.

The overall yield levels were considerably lower on red soil than on black; and on black soil they were lower than in previous years. For example in 1974/5 in an nearby part of the same field we obtained 1700 kg/ha yield from cv ICP-1, compared with only 1000 kg/ha in the control plots this year. The low yields this year are probably a consequence of moisture stress resulting from the failure of the monsoon rains in September; this stress would have been more pronounced on red soil than on black owing to the lower water-holding capacity of the red soil.

There was no significant effect of nitrogenous fertilizer on 100-seed weight or seed number per pod on red soil, but on black soil the N_{20} and FYM treated plants had slightly higher 100-seed weights than the controls (Table 8).

The lack of effect of the nitrogenous fertilizer on yield indicates that in the control plants nitrogen fixation by the nodules was providing sufficient nitrogen to the plants.

Table 6. Quantity and composition of plant material which had fallen by the time of harvest from plants of cv. ICP-1 grown on black soil (data from 9 m^2 subplots).

Treatments	Quantity of fallen materials kg/ha				% of total		
	Leaf	Flowers	Pods	Total	Leaf	Flowers	Pods
N_0	1486	211	31	1728	86	12	2
N_{200}	1929	204	39	2172	89	9	2

Table 7. Effects of fertilization with nitrogen or farmyard manure on yield, total shoot dry weight, fallen leaves and harvest index of cv. ICP-1 grown on black and red soils.

Treatments	Yield (kg/ha)	Shoot total dry weight at harvest (kg/ha)	Fallen leaves (kg/ha)	Shoot total dry weight + fallen leaves (kg/ha)	Harvest Index (%)	Corrected HI taking fallen leaves into account
BLACK SOIL:						
N_0	1007	3941	2157	6099	25.6	16.6
N_{20}	1141	4613	2515	7123	24.9	16.0
N_{200}	1072	4818	3664	8281	22.5	13.2
FYM	1044	4300	2380	6680	24.3	15.6
LSD (5%)	144.9(NS)	622.8	1145.9	1144.8	5.09(NS)	3.54(NS)
SE+	90.5	393.1	716.4	715.7	3.18	2.21
CV%	8.5	8.9	27.3	10.2	13.1	14.4
RED SOIL:						
N_0	696	4732	1715	6448	14.3	10.5
N_{20}	571	4023	1486	5509	14.3	10.6
N_{200}	478	4244	1504	5748	11.1	8.2
FYM	555	3810	1071	4882	14.3	11.1
LSD (5%)	230.5(NS)	1389.0(NS)	800(NS)	2045.3(NS)	4.06(NS)	2.98(NS)
SE+	144.1	868.4	500	1271.8	2.54	1.86
CV%	25.1	20.7	34.6	22.6	18.8	18.5

Table 8. Effects of nitrogenous fertilizer and farmyard manure on seed number per pod and 100-seed weight of cv. ICP-1 grown on black and red soil.

Treatments	Seed number per pod		100-seed weight (g)	
	Black soil	Red soil	Black soil	Red soil
N_0	2.90	2.89	8.70	8.70
N_{20}	2.97	2.77	9.70	8.70
N_{200}	2.84	2.76	9.20	8.80
FYM	2.86	2.91	9.50	9.00
LSD (5%)	0.128	0.244(NS)	0.57	0.62(NS)
CV (%)	2.80	5.40	3.80	4.40

D. Nitrogen uptake and distribution

The percentage nitrogen content of different organs throughout the growing season are shown in Fig.6 for N_0 and N_{200} treatments on black and red soils.

In all cases the nitrogen content of leaf laminae, petioles, stems and peduncles declined with time. The patterns of decline and also the percentage nitrogen contents of the control (N_0) plants closely resemble those observed previously (see PPR 1975/6 Fig.20).

The soil type seemed to have little effect on nitrogen content except that on red soil in the early stages of growth the stems had a higher nitrogen content than on black soil. On both soils nitrogen fertilization resulted in a higher nitrogen content of the stems and petioles but had little effect on the percentage of nitrogen in the leaf laminae.

The uptake and distribution of nitrogen in the different parts of the plants are shown in Fig.7. The greater amount of nitrogen in the nitrogen-fertilized plants largely reflects their greater growth (compare Fig.7 with the dry matter accumulation curves in Fig.2). It is particularly noticeable that the N_{200} treatment resulted in much larger amounts of nitrogen in the stems; moreover, nitrogen continued to accumulate in the stems throughout the reproductive phase whereas in the controls the nitrogen content of the stems declined slightly.

FIG. 6: CHANGES IN PERCENTAGE NITROGEN CONTENT OF PLANT PARTS OF PIGEONPEA CV. ICP-1 GROWN AT TWO LEVELS OF NITROGEN

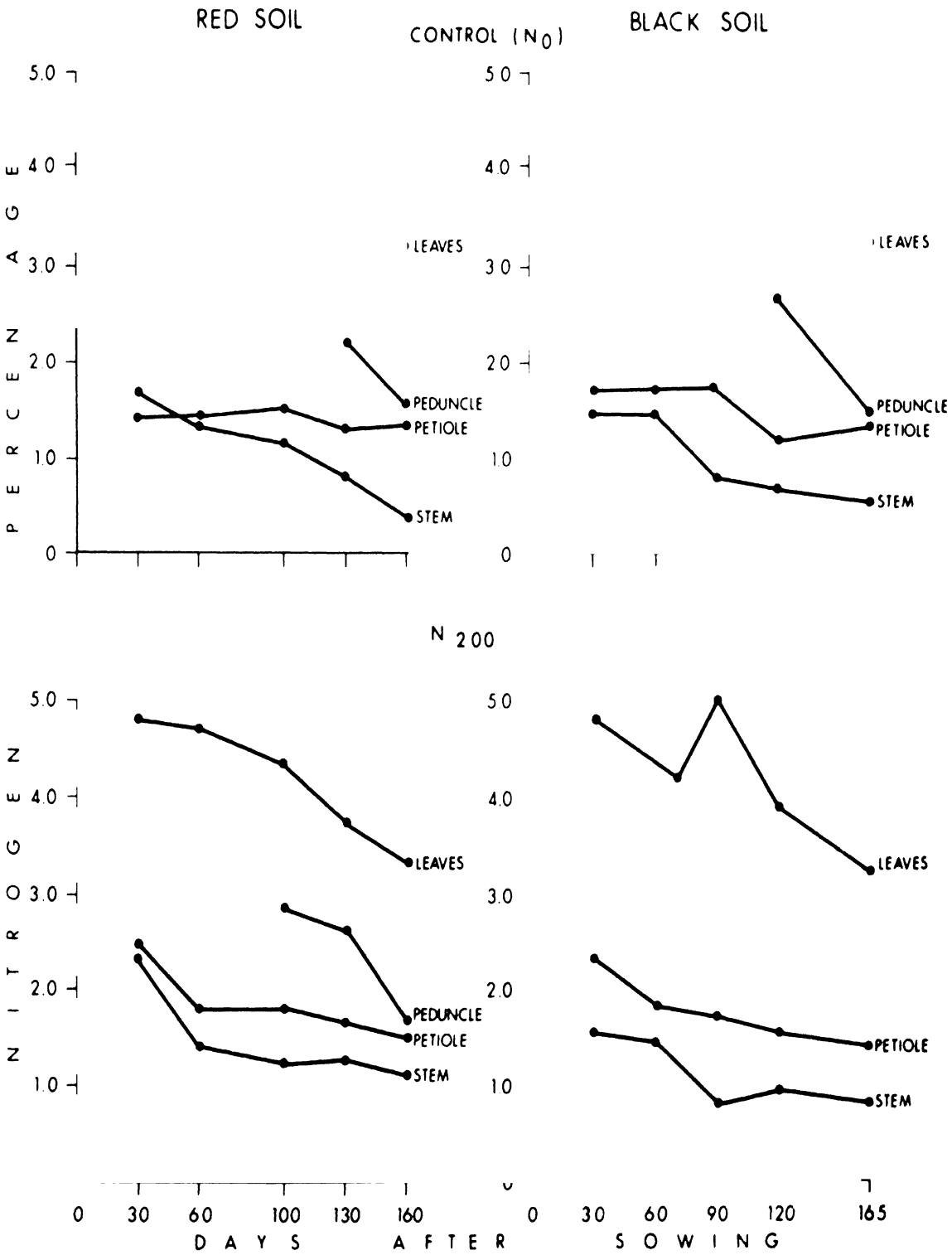
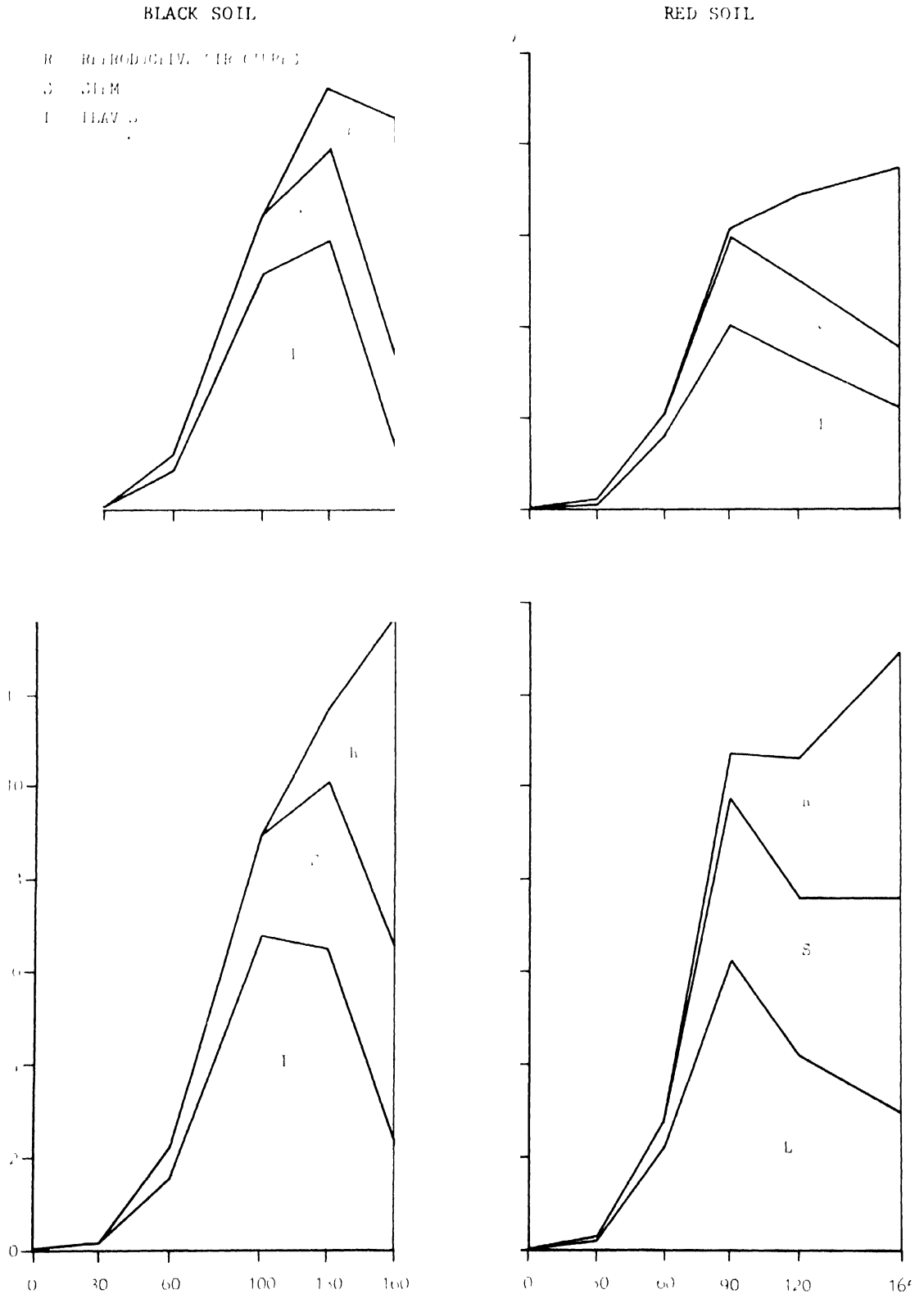


FIGURE 7. UPTAKE AND DISTRIBUTION OF NITROGEN BY PIGEONPEA CV ICP-1 GROWN AT TWO LEVELS OF NITROGEN



Both in the controls and the N_{200} treated plants up to 60 days after sowing the nitrogen content was greater in the plants grown on red soil than on black. A relative advantage of plants grown on red soil in nitrogen uptake at least in the earlier stages of growth has been observed in previous years (see PPR 1975/6 Fig.19 and Table 15). These differences may be related to the fact that the nodules produced in red soil are generally bigger and better than those in black soil.

The nitrogen content of the fallen leaves, fallen flowers and fallen pods from the control and N_{200}-treated plants grown on black soil is shown in Table 9. There was a certain amount of variation in the percentage of nitrogen in these fallen organs collected at different times but no clear-cut trend was apparent.

The rates of nitrogen uptake and also the crop growth rates for the control and N_{200}-treated plants grown on black soil were calculated taking the dry matter and nitrogen content of the fallen plant parts into account. The results are shown in Fig. 8. Both in the controls and the nitrogen fertilized plants, the rate of nitrogen uptake was at a maximum 90-120 days after sowing when the crop growth rate was falling; nitrogen uptake was not parallel to overall growth. During the reproductive phase (120-165 days) the rate of nitrogen uptake, though lower than in the immediately preceding period, was still fairly high, similar to that in the 60-90 day period during the vegetative phase. The rate of phosphorus uptake (see below) was calculated for the control plants; this rate changed in a similar way to the rate of nitrogen uptake (Fig. 8).

The total dry matter produced and the total amount of nitrogen taken up by the control and N_{200}-treated plants grown on black soil is shown in Table 10. Fertilization with 200 kg/ha nitrogen resulted in a increased nitrogen uptake of only 42 kg/ha on black soil and 16 kg/ha on red soil. There was little or no increase in the nitrogen content of the seeds; the extra nitrogen taken up was present in the stems and, on the black soil, in the fallen leaves.

Last year we found that cv. ICP-1 grown on black soil without nitrogenous fertilizer took up 108 kg/ha nitrogen (see PPR 1975/6 Table 13); the uptake this year of 82 kg/ha reflects the lesser growth of the stems and the reduced seed yield. In both years just over 2 tons/ha of fallen leaves were returned to the soil containing 32 kg/ha nitrogen.

On both red and black soils than majority of the nitrogen in the green leaves was remobilized into the plant during the process of senescence. The actual percentages remobilized can be calculated from the changes in specific leaf weight and the nitrogen percentages of green and fallen leaves (see Tables 40 and 42); for cv. ICP-1 grown

Table 9. Percentage nitrogen content of fallen plant parts collected at different times.

Days after sowing	N_0			N_{200}		
	Leaves	Flowers	Pods	Leaves	Flowers	Pods
100	1.57	-	-	1.52	-	-
107-114	1.26	-	-	1.30	-	-
121-128	1.22	1.88	-	1.21	1.79	-
136-149	1.45	2.20	2.76	1.67	2.37	2.84
156-163	1.92	2.30	2.59	1.80	2.06	3.03
170-174	1.48	2.07	2.85	1.64	2.20	3.11

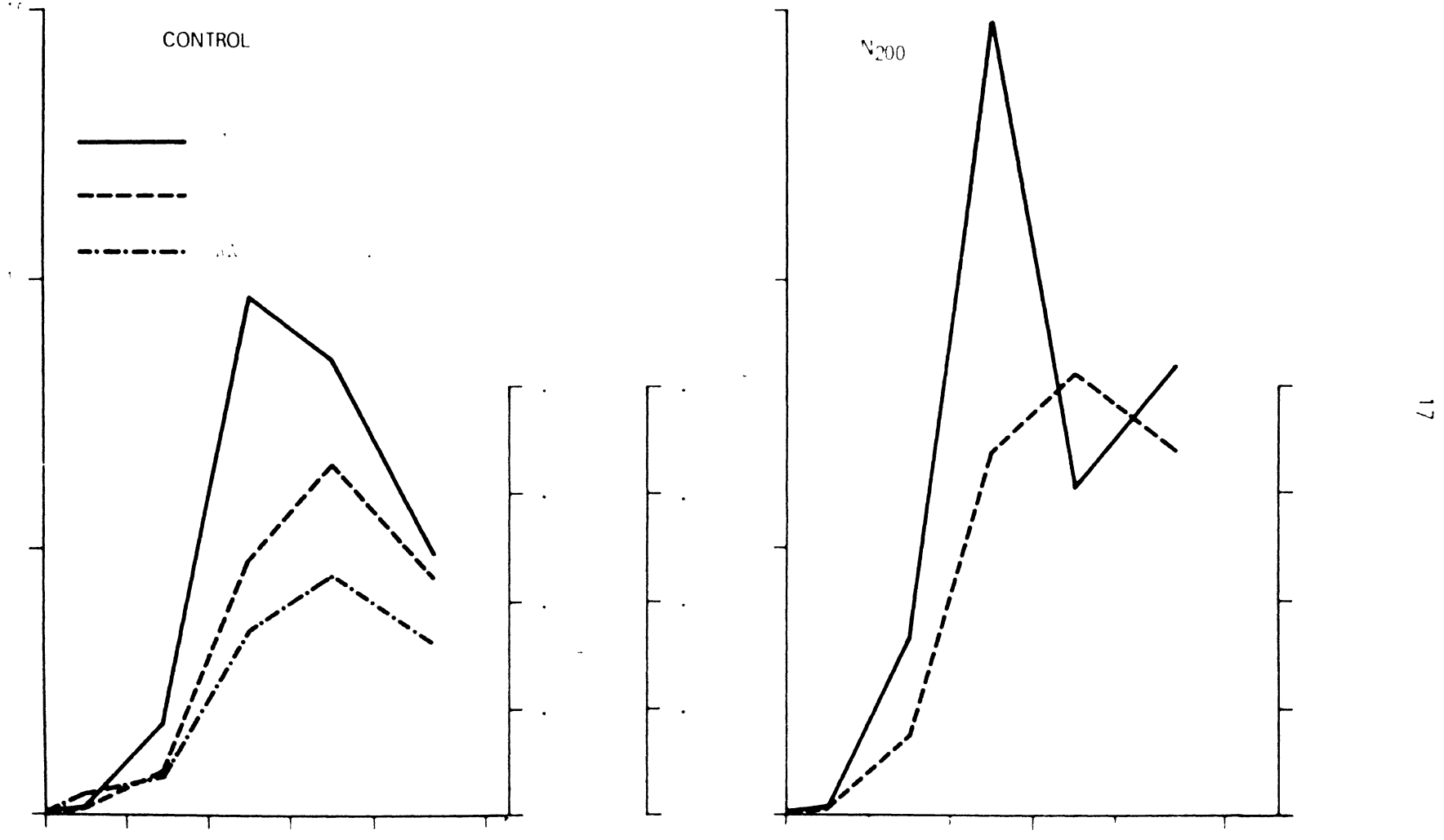
Table 10. Dry matter production and nitrogen uptake by cv. ICP-1 at the time of harvest on black and red soils without nitrogenous fertilizer and with 200 kg/ha N.

Plant part	N_0			N_{200}		
	Dry matter (kg/ha)	Nitrogen percentage	Nitrogen (kg/ha)	Dry matter (kg/ha)	Nitrogen percentage	Nitrogen (kg/ha)
BLACK SOIL:						
Seed	1007	3.45	34.7	1072	3.62	38.8
Pod wall	428	0.68[a]	2.9	448	0.68[a]	3.0
Stem	2423	0.53	12.8	3409	0.79	26.9
Fallen leaves	2157	1.48	31.8	3664	1.52	55.7
Total	6015	-	82.2	8593	-	124.4
RED SOIL:						
Seed	696	3.38	23.5	478	3.72	17.8
Pod wall	296	0.68[a]	2.0	200	0.68[a]	1.4
Stem	3740	0.42	15.7	3566	1.13	40.3
Fallen leaves	1715	1.31[b]	22.5	1504	1.31[b]	19.7
Total	6447	-	63.7	5748	-	79.2

Note: (a) Not analysed: values shown are for nitrogen percentage in pod walls of cv. ICP-1 grown in 1975/6 without nitrogen fertilizer

(b) Not analysed: the values shown are taken from analysis of fallen leaves of cv. ICP-1 grown on red soil in field R-1 without nitrogen fertilizer.

FIGURE 8. CROP GROWTH RATE (CGR) AND RATES OF NITROGEN AND PHOSPHORUS UPTAKE BY THE SHOOT SYSTEM (INCLUDING FALLEN PLANT PARTS) OF CV ICP-1 GROWN ON BLACK SOIL WITH AND WITHOUT NITROGENOUS FERTILIZER



without nitrogen fertilizer on red soil the percentage of nitrogen remobilized was 78% and on black soil 84%. Thus the nitrogen in the fallen leaves represents less than a quarter of the amount present in the same leaves when they were green. Thus more than three times the amount in the fallen leaves was remobilized into the plant. This comes to about 90 kg/ha for the N_0 plants on black soil and about 70 kg/ha for those on red soil. These quantities are slightly greater than the total amount of nitrogen in the whole of the shoot system, including fallen leaves (Table 10). This is a surprising result and suggests nitrogen remobilization may have been overestimated. But even if only about half the nitrogen were remobilized from leaves as they senescenced, this would be able to account for all the nitrogen in the seeds, indicating the importance of nitrogen remobilization from the leaves. Last year, when yields were higher, we estimated that 83% of the nitrogen in the grain could have been remobilized from the leaves (see PPR 1975/6 Section 1.5).

Perhaps the most important reason why these calculations may have overestimated nitrogen remobilization is that they indicate the gross remobilization of nitrogen. Since some of the leaves fall early in the reproductive phase (Fig. 5) while new leaves are still being formed, nitrogen could be remobilized from old into new leaves; subsequently it could be remobilized again from these leaves as they themselves senescence. Thus net remobilization of nitrogen from leaves to other parts of the plant would be less than gross remobilization.

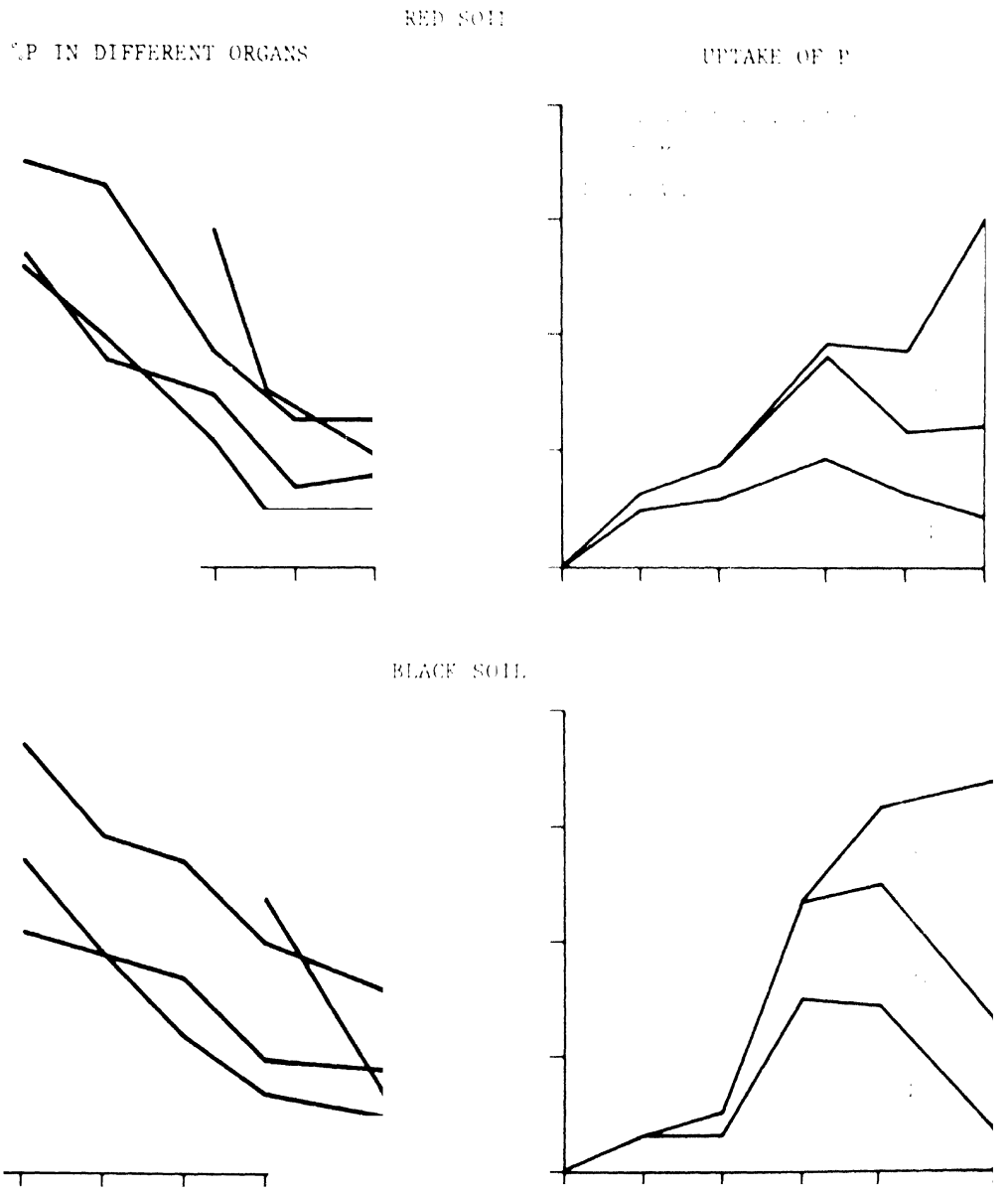
E. Phosphorus uptake and distribution

The uptake and distribution of phosphorus were investigated in the control (N_0) plants grown on black and red soils.

The percentage phosphorus content of the leaves, petioles and stems declined throughout the growing season, and the percentage in the peduncles also declined before harvest (Fig. 9). The uptake of phosphorus continued up until the time of harvest (Fig. 9). There was a remobilization of P from leaves and stems during the reproductive phase, presumably into the developing pods. The rate of phosphorus uptake was calculated for the plants grown on black soil, taking the fallen leaves into account. This rate, like that of nitrogen uptake, was at a maximum during the 90-120 day period when the crop growth rate was decreasing (Fig. 8).

The total phosphorus uptake by the above-ground parts of the plants grown on black soil was 5.6 kg/ha (Table 11). Of this 1.3 kg/ha was returned to the soil in the form of fallen leaves. Since mature green leaves contain about 0.30% phosphorus and fallen leaves only 0.06%, over 5 kg/ha of phosphorus could have been remobilized from the leaves

FIGURE 9. PHOSPHORUS CONTENT AND DISTRIBUTION IN DIFFERENT PLANT PARTS OF PIGEONPEA CV ICP-1 ON RED AND BLACK SOILS THROUGHOUT THE GROWING SEASON.



as they senesced. This would have been more than enough to account for all the phosphorus in the seeds.

F. Nitrogen and Phosphorus content of different parts of the stem.

In the later stages of growth the large amount of stem material per plant limits the number of plant samples which can be pooled for grinding prior to chemical analysis. The optimum sampling procedure would depend on the variation between and within plants. This year we studied the variation within plants by comparing the nitrogen and phosphorus content of (a) main stems and branches, and (b) the upper, middle and basal part of the stem including both main stem and branches. For each of these comparisons two or three plants per sampling date per treatment were used. The entire stem of another plant was ground up to give a "total" stem sample. The results of the analysis for nitrogen are shown in Table 12 and for phosphorus in Table 13.

In general, the branches contained a higher percentage of nitrogen than the main stems and the upper parts of the plants contained more than the middle parts which in turn contained more than the basal parts. A similar pattern was found for phosphorus, but the differences were less pronounced.

Table 11. Phosphorus uptake at the time of harvest by pigeonpea cv. ICP-1 grown on black soil without nitrogenous fertilizer.

Plant	Dry matter (kg/ha)	Phosphorus percentage	Phosphorus (kg/ha)
Seed	1007	0.29	2.9
Pod wall	428	0.03	0.1
Stem	2423	0.05	1.2
Fallen leaves	2157	0.06	1.3
Total	6015	-	5.5

Table 12. Percentage of nitrogen in total stem material in branches and main stem and in the upper, middle and basal parts of the stem of plants of cv. ICP-1.

Treatment	Soil	Days after sowing	N% in stem material						Roots
			Total	Main stem	Branches	Upper	Middle	Basal	
N_0	Black	90	0.80	0.72	1.07	1.44	0.78	0.66	-
N_0	Black	120	0.66	0.69	0.94	1.29	0.75	0.74	0.68
N_0	Black	165	0.53	0.48	0.75	0.67	0.60	0.48	0.53
N_{200}	Black	90	0.82	0.73	1.21	1.48	0.99	0.83	-
N_{200}	Black	120	0.98	0.98	1.21	1.06	1.06	0.85	0.92
N_{200}	Black	165	0.73	0.62	1.00	0.93	0.76	0.69	0.83
N_0	Red	100	1.16	0.99	1.29	1.05	1.24	1.13	-
N_0	Red	130	0.80	0.81	0.91	1.20	0.97	0.78	-
N_0	Red	160	0.42	0.61	0.78	1.09	0.75	0.70	-
N_{200}	Red	100	1.25	0.86	1.48	1.74	1.13	1.11	
N_{200}	Red	130	1.28	1.00	1.33	1.63	1.17	1.03	
N_{200}	Red	160	1.13	1.03	1.22	1.17	1.17	0.90	

Table 13. Percentage of phosphorus in total stem material in branches and main stems and in the upper middle and basal parts of plants of cv. ICP-1 grown without nitrogenous fertilizer on black and red soils.

Soil	Days after sowing	Total	Main stem	Branches	Upper	Middle	Basal	Roots
Black	90	0.12	0.12	0.15	0.17	0.11	0.11	-
	120	0.07	0.08	0.08	0.10	0.06	0.06	0.06
	165	0.05	0.04	0.04	0.04	0.04	0.03	0.04
Red	100	0.11	0.12	0.13	0.11	0.13	0.14	-
	130	0.05	0.05	0.05	0.08	0.05	0.04	-
	160	0.05	0.04	0.04	0.05	0.05	0.04	-

The branches and the upper parts of the plants probably contain more nitrogen and phosphorus because they have a higher proportion of living, cytoplasm-containing cells. The older woodier parts of the plants have a higher proportion of dead, lignified tissue. The decline with time of nitrogen and phosphorus percentages in all parts of the stem probably reflects a mobilization of compounds from storage tissues (e.g. xylem parenchyma) and perhaps also a decline in the proportion of cytoplasm-rich cambial cells.

The results indicate that in preparing stem samples for analysis, all parts of the stem should be included in the correct proportions. The preferential use of easy-to-grind branches or upper parts of the stem will introduce substantial errors.

From the black soil the roots from the surface zones of the soil were also analysed. Their nitrogen and phosphorus contents were similar to those of the "total" stem material.

The upper part of the root system, like the lower part of the stem system, contains older, woodier material with a lower nitrogen percentage than that found in the deeper zones of the soil (see Section 1.2 below).

G. Nodulation and nitrogenase activity

The following is a summary of the observations which will be described in detail in the ICRISAT Pigeonpea Microbiology Report for 1976/7.

In black soil 30 days after sowing the N_{20} treatment resulted in a reduction of about 25%, and N_{200} in a reduction of about 50%, in nodule number, nodule weight and nitrogenase activity per plant. The plants in the farm yard manure treatment did not differ significantly from the controls. At both 60 and 90 days after sowing there were no significant differences in nodule numbers, nodule mass or nitrogenase activity.

On red soil, samples were taken at 30, 60 and 125 days after sowing; in all there was some reduction in nodule numbers and nodule mass in the N_{200}-treated plants but the reductions were small (around 25%) and not statistically significant at the 5% level. There were no significant effects of the treatments on nitrogenase activity.

I.2

THE SHOOT/ROOT RATIO OF PLANTS AT THE TIME OF HARVEST

It is difficult to obtain an accurate estimate of the mass of the root system of a deep-rooted crop such as pigeonpea. It is usually only feasible to excavate the more superficial woody part of the root system; the proportion of the root system which is left behind is unknown.

In order to obtain some estimate of the total mass of the root system, the shoot/root ratio and the relative weights of the superficial woody easily-extractable roots and the rest of the root system, we grew plants of cv. T-21 in black and red soils in brick chambers 1.5 m deep (of cross-section 50 x 70 cms for black soil and 50 x 50 cms for red soil). The soil was fertilized with $ZnSO_4$ and single superphosphate at rates equivalent to 40 kg/ha and 45 kg/ha respectively. Seeds were sown in the chambers at the onset of the monsoon. The seedlings were nodulated. The plants were grown to maturity. At the time of harvest one wall of the brick chamber was removed and the soil was carefully washed away from the roots, exposing the entire root system. The upper part of the root system, corresponding to roots extractable by superficial excavation in the field, and the remainder of the root system were collected separately. Lengths of the roots and stems were measured and the dry weights of the various plant-parts were taken. The results are shown in Table 14 for four plants grown in black soil and for three plants grown in red soil.

About two thirds to ~~those~~ Three quarters of the total root mass were in the upper readily-extractable part of the root system. The shoot/root ratios were higher on black soil than on red. In both soils the shoot/root ratios were overestimated considerably when the lower part of the root system was ignored.

The percentage of nitrogen was generally higher in the lower part of the root system than in the more woody upper roots (Table 15). This is analogous to the higher percentage of nitrogen found in the upper part of the stem system than in the woodier lower part (See Table 12).

Table 14. Lengths and weights at the time of harvest of root and shoot systems of plants of cv. T-21 grown in black or red soil in brick chambers.

Soil and plant No.	Stem length (cm)	Root length	Shoot dry weights (g)				Root dry weight (g)			Roots		
			Stem dry wt.	Leaves dry weight	Pods dry wt.	Total shoot dry wt.	Upper roots	Lower roots	Total roots	Upper root/ total root	Total shoot/ total root	Total shoot/ upper roots
Black 1	161	176	189	20	39	248	40	20	60	0.67	4.1	6.2
Black 2	129	183	264	30	30	324	51	23	74	0.69	4.4	6.4
Black 3	131	186	168	24	16	208	38	10	48	0.79	4.3	5.5
Black 4	171	134	60	5	20	85	16	6	22	0.73	3.9	5.3
Mean	148	170	170	20	26	216	20	15	51	0.72	4.2	5.9
Red 1	138	153	118	24	16	159	28	16	44	0.64	3.6	5.7
Red 2	110	165	26	2	7	35	8	3	10	0.80	3.6	4.4
Red 3	113	128	14	1	3	18	4	1	5	0.80	3.2	4.5
Mean	120	149	53	9	9	71	13	7	20	0.75	3.5	4.9

Table 15.. Nitrogen percentage in upper and lower roots at the time of harvest of plants of cv. T-21 grown in black and red soil in brick chambers

Soil and plant number		PERCENTAGE NITROGEN	
		In upper roots	In lower roots
Black	1	0.92	1.07
Black	2	0.85	0.99
Mean		0.89	1.03
Red	1	1.02	1.25
Red	2	1.26	0.84
Red	3	0.90	1.09
Red	4	1.04	1.21
Mean		1.06	1.10

SECTION-II

EXPERIMENTAL INVESTIGATIONS ON SOURCE-SINK RELATIONSHIPS

We carried out a number of investigations on plants grown in the field in an attempt to find out more about the factors controlling pod-set and yield. The sizes of the photosynthetic source and the reproductive and vegetative sinks were altered by defoliation during the reproductive phase of the plants, by the removal of flowers and by the removal of vegetative meristems. Some preliminary experiments of these types were described in PPR 1975/6, Section II; this year the experiments were carried out in more detail in replicated plots with five cultivars, Pusa ageti, T-21, ICP-1, ICP-6997 and HY-3A.

Methods

i) Experiments involving flower removal and defoliation:

The flower removal and defoliation experiments were carried out in black soil in field B-5. The date of sowing was 1-7-76. Two early cultivars (T-21 and Pusa ageti) were sown in flat seed beds at a spacing of 50 x 30 cm. Fifteen plots (9 x 6 m) of each cultivar were sown. Two adjacent rows of plants (together containing about 60 plants) were used for each treatment within each replication; leaving one row on either side as a border row.

Three medium duration cultivars (ICP-1, ICP-6997 and HY-3A) were sown on ridges spaced 75 cms apart at a plant to plant spacing of 75 x 30 cms in 9 x 9 m plots. Fifteen plots of cv. ICP-1, 7 of ICP-6997 and 8 of HY-3A were sown. Each treatment was carried out on two adjacent rows of plants (together containing about 60 plants) within each replication. For cvs. ICP-1 and HY-3A four replicates were used; for cv. ICP-6997 there were three replications. No border rows were left between the treated rows within the plots, but the border rows of the plots themselves were not treated and were discarded at the time of harvest.

In all cultivars, the treatments were randomly assigned within each replication: thus the design was an RBD. Within each cultivar, statistical analyses of the flower removal and leaf removal experiments were carried out separately.

The dates at which 50% of the plants began flowering and the dates of harvest of the different cultivars are shown in Table 16.

Table 16. Dates of 50% flowering and of harvest of the plants used for experiments on source-sink relationships.

CULTIVAR	Date of 50% flowering	Date of harvest
Pusa ageti	18-9-76	17-11-76
T-21	21-9-76	19-11-76
ICP-1	19-10-76	11-1-76
ICP-6997	20-10-76	12-1-77
HY-3A	15-11-76	12-1-77

In flower removal treatments, all flowers (and young pods if any) were removed by hand on the dates given below, and the oven-dry weights of the removed flowers were recorded. In leaf removal treatments, different proportions of leaves were removed as described in PPR 1975/6, Table 17 from the time of 50% flowering onwards on the dates indicated below. The oven-dry weight of the removed leaves was recorded.

The senescent leaf removal treatment involved removing the lower leaves which were senescent or had just begun to turn yellow. Their oven-dry weights were recorded. The absolute controls were not treated in any way. In the 'controls' the leaves of each plant were counted on the dates indicated.

The treatments in the different cultivars were as follows:

Cv. Pusa ageti:

Absolute control

Control (leaf counting on 25-9-76; 10-10-76; 24-10-76)
Flower removal for 1 week (on 20-9-76)
Flower removal for 2 weeks (on 20-9-76; 28-9-76)
Flower removal for 3 weeks (on 20-9-76; 29-9-76; 6-10-76)
Flower removal for 4 weeks (on 20-9-76; 30-9-76; 7-10-76; 13-10-76)
Flower removal for 7 weeks (on 20-9-76; 30-9-76; 6-10-76; 12-10-76; 20-10-76; 29-10-76; 3-11-76)
Removal of senescent leaves (on 24-9-76; 1-10-76; 7-10-76; 13-10-76; 20-10-76)

Cv. T-21:

(a) Flower removal experiments:

Absolute Control

Control (leaf counting on 29-9-76; 10-10-76; 23-10-76)
Flower removal for 1 week (on 21-9-76)
Flower removal for 2 weeks (on 21-9-76; 30-9-76)
Flower removal for 3 weeks (on 21-9-76; 1-10-76; 7-10-76)
Flower removal for 7 weeks (on 21-9-76; 1-10-76; 7-10-76; 13-10-76; 20-10-76; 28-10-76; 3-11-76)
Flower removal from alternative flowering nodes (on 23-9-76; 5-10-76; 12-10-76; 18-10-76)
Flower removal from alternate branches (on 22-9-76; 5-10-76; 12-10-76; 18-10-76)

(b) Defoliation experiments:

Absolute Control

Control (leaf counting on 29-9-76; 10-10-76; 23-10-76)
1/3 leaves removed (on 22-9-76; 5-10-76; 11-10-76; 18-10-76)
1/2 leaves removed (on 22-9-76; 4-10-76; 11-10-76; 18-10-76)
2/3 leaves removed (on 23-9-76; 4-10-76; 12-10-76; 18-10-76)
3/4 leaves removed (on 23-9-76; 4-10-76; 12-10-76; 18-10-76)
All leaves removed (on 21-9-76; 29-9-76; 7-10-76; 13-10-76; 20-10-76)
All leaves removed from alternate branches (on 22-9-76; 4-10-76; 11-10-76; 18-10-76)
Senescent leaves removed (on 4-9-76; 5-10-76; 11-10-76; 18-10-76)

Cv. ICP-1:

Absolute Control

Control (leaf counting on 31-10-76; 13-11-76; 5-12-76)

(a) Defoliation experiments:

1/3 leaves removed (on 27-10-76; 4-11-76; 11-11-76; 18-11-76; 25-11-76; 29-11-76)
1/2 leaves removed (ditto)
2/3 leaves removed (ditto)
3/4 leaves removed (ditto)
All leaves removed (ditto)
All leaves removed from alternate branches (ditto)
Senescent leaves removed (on 27-10-76; 3-11-76; 10-11-76; 18-11-76; 23-11-76; 30-11-76; 6-12-76)

All leaves removed 3 weeks after 50% flowering (on 11-11-76; 18-11-76; 24-11-76; 30-11-76; 6-12-76)
All leaves removed 5 weeks after 50% flowering (on 24-11-76; 30-11-76; 6-12-76)

(b) Flower removal experiments:

Flower removal for 2 weeks (on 25-10-76; 1-11-76)
Flower removal for 3 weeks (on 25-10-76; 1-11-76; 18-11-76)
Flower removal for 4 weeks (on 26-10-76; 2-11-76; 9-11-76; 16-11-76)
Flower removal for 5 weeks (on 26-10-76; 2-11-76; 9-11-76; 16-11-76; 23-11-76)
Removal of racemes from alternate nodes (on 30-10-76; 8-11-76; 12-11-76; 18-11-76; 24-11-76; 30-11-76)
Flower removal from alternate branches (on 26-10-76; 3-11-76; 10-11-76; 18-11-76; 23-11-76; 30-11-76)
Flower removal from all the lower branches of the plants (ditto)
Flower removal from all the upper branches of the plants (ditto)

Cv. ICP-6997:

Absolute Control

Control (leaf counting on 1-11-76; 13-11-76; 5-12-76)
1/2 leaves removal (on 26-10-76; 3-11-76; 10-11-76; 17-11-76; 29-11-76)
All leaves removed (ditto)
All leaves removed from alternate branches (ditto)
Senescent leaves removed (on 27-10-76; 3-11-76; 10-11-76; 17-11-76; 23-11-76; 29-11-76; 6-12-76)
Flower removal for 2 weeks (on 20-10-76; 1-11-76)
Flower removal for 3 weeks (on 20-10-76; 1-11-76; 8-11-76)
Flower removal for 4 weeks (on 20-10-76; 1-11-76; 8-11-76; 15-11-76)
Flower removal for 5 weeks (on 20-10-76; 1-11-76; 8-11-76; 15-11-76; 23-11-76)
Flower removal from alternate branches (on 27-10-76; 3-11-76; 10-11-76; 17-11-76; 23-11-76; 29-11-76)

Cv. HY-3A:

Absolute Control

Control (leaf counting on 13-11-76; 5-12-76; 2-1-77)
1/2 leaves removed (on 12-11-76; 19-11-76; 25-11-76; 3-12-76; 10-12-76; 17-12-76; 29-12-76).
All leaves removed (ditto)
All leaves removed from alternate branches (ditto)
Senescent leaves removed (ditto)
Flower removal for 2 weeks (on 15-11-76; 22-11-76)

Flower removal for 3 weeks (on 15-11-76; 22-11-76; 29-11-76)
Flower removal for 4 weeks (on 15-11-76; 22-11-76; 29-11-76; 6-12-76)
Flower removal for 5 weeks (on 15-11-76; 22-11-76; 29-11-76; 6-12-76; 13-12-76).
Flower removal from alternate branches (on 12-11-76; 18-11-76; 3-12-76; 10-12-76; 17-12-76; 29-12-76).

In all cultivars samples of 5 adjacent plants from each replicate were taken for growth analysis at the time of 50% flowering and from each treatment in each replicate during the mid-reproductive phase. At the time of harvest, total dry weight of the shoot system, pod number, pod dry weight, seed number and seed dry weight were recorded. In cvs. Pusa ageti and T-21 the plants from which flowers were removed for 7 weeks were left to mature after the other plants had been harvested; these plants were badly damaged by insects since insecticide sprays were accidentally omitted. The damaged and undamaged pods were collected separately and the yield corrected by multiplying the number of damaged pods (which were 33% of the total in cv. T-21 and 53% in Pusa ageti) by the seed yield per pod in the undamaged pods.

(ii) Experiment on the effects of the removal of vegetative meristems during the reproductive phase:

The experiment was carried out with cv. T-21 grown on red soil (field R-1). The date of sowing was 7-7-76. The plants were sown on flat soil at a spacing of 50 x 30 cms in 9 x 6 m plots. Five plots were used in this experiment. Two rows of plants within the plots were used for each treatment and the treatments were replicated 5 times in a randomized block design. The treatments were as follows:

1. Control

2. Removal of apical buds from the main stem and branches at the time of flower bud initiation (9-9-76).

3. Removal of apical buds from the main stem and branches at the time of 50% flowering (21-9-76).

At the time of harvest (2-11-76) total shoot dry weight, yield and yield components were recorded.

II.1

EFFECT OF MANIPULATION OF THE PLANTS ON GROWTH AND YIELD

Mechanical stimulation brought about by handling or manipulating plants is known to have an effect on the growth and development of young plants of a number of species, probably as a consequence of the production of ethylene (see Jaffe, M.J. (1973)) 'Thigmomorphogenesis: The response of plant growth and development to mechanical stimulation' Planta 114, 143-157). Therefore, it seemed possible that the manipulations involved in our various defoliation and flower-removal experiments might have an effect on growth and yield over and above the effects of the actual treatments given. We therefore incorporated at least two control treatments in each set of experiments. The plants in one of the controls, the 'absolute control', were not touched or manipulated at all; in the other control the leaves of the plants were counted at regular intervals. The boys who did the leaf-counting moved between the plants, bent the stems and touched the leaves during this process, and hence these plants were mechanically stimulated.

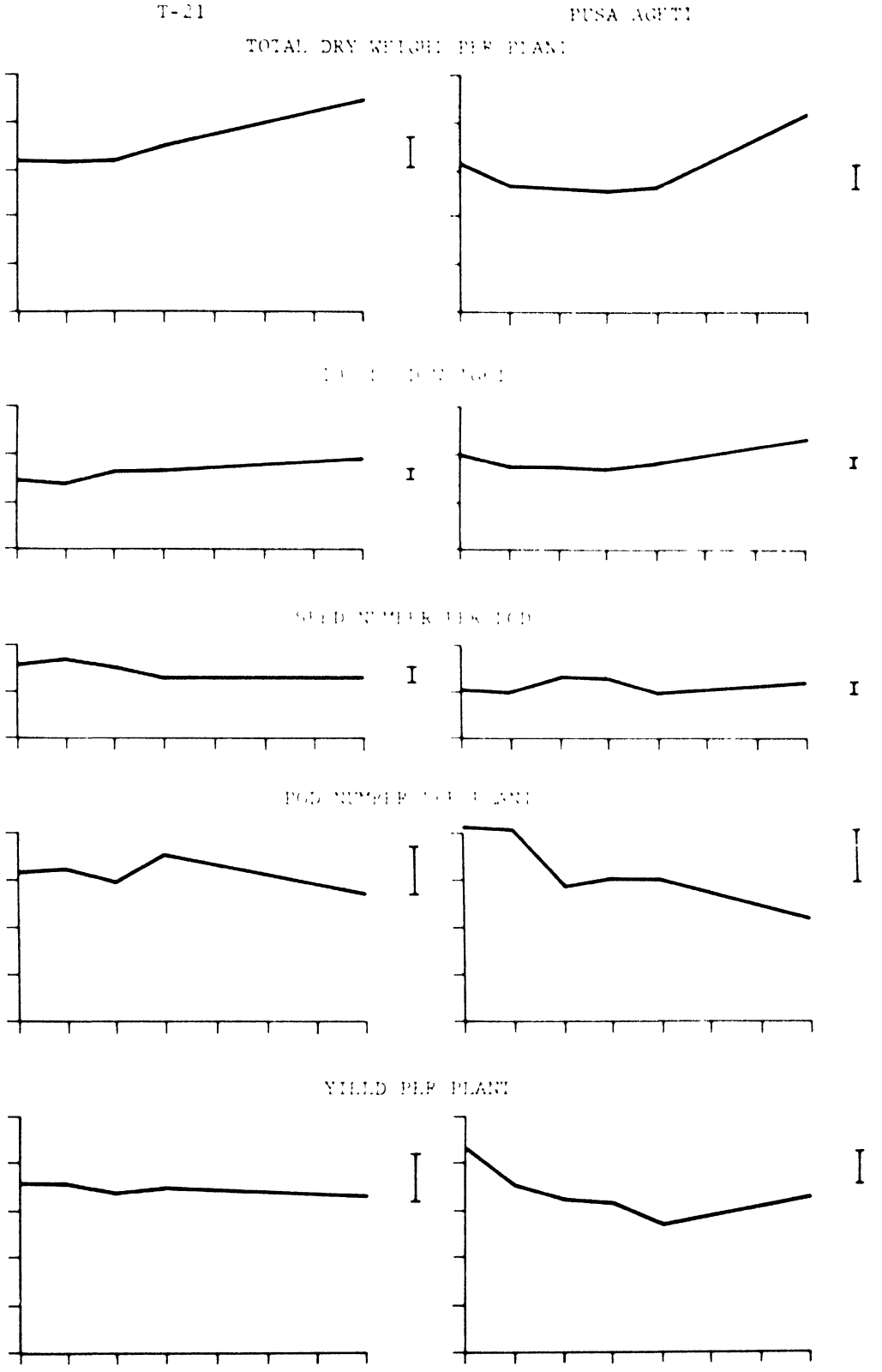
In none of the cultivars did this mechanical stimulation have any significant effect on yield (Table 17) or on total shoot dry weight at harvest, or on yield components. Probably the mild stimulation brought about by the manipulation of the plants was relatively insignificant compared with that experienced by the plants every day as a result of the wind, if indeed mechanical stimulation has any effect on pigeonpeas.

In the experimental results described below the control values shown are the mean of the 'absolute' and mechanically-stimulated control values given in Table 17.

Table 17. Yields per plant of absolute controls and control plants which were manipulated during the reproductive phase.

Cultivar	YIELD PER PLANT (g) Absolute control	Manipulated control	LSD (5%)
Pusa ageti	17.3	17.0	2.88
T-21 (Flower removal experiments)	13.6	15.0	3.10
T-21 (Defoliation experiments)	13.6	14.6	3.98
ICP-1	27.8	29.6	4.06
ICP-6997	23.2	19.3	5.18
HY-3A	12.6	13.6	3.72
Mean	18.0	18.2	

FIGURE 10. EFFECT OF DIFFERENT PERIODS OF FLOWER REMOVAL ON TOTAL SHOOT DRY WEIGHT, YIELD AND YIELD COMPONENTS OF CVS T-21 AND PUSA AGETI. LSD (5%) ARE INDICATED BY BARS.



II.2

EFFECTS OF FLOWER REMOVAL FOR DIFFERENT LENGTHS OF TIME

Pigeonpeas generally continue flowering for several weeks, but the great majority of the flowers drop off without setting pods. The percentage of pod-set is the highest with the earlier-formed flowers. However if these earlier-formed flowers are removed and hence prevented from setting pods, a higher proportion of the later-formed flowers set pods; furthermore, if pod set is prevented by flower removal for a protracted period, the growth of the racemes and the production of flowers continues for a longer period than usual. Thus the plants are able to compensate by setting pods from later-formed flowers when pod-set is prevented during the earlier part of the reproductive phase (see PPR 1975/6 Section II.2).

This year, flowers were removed from plants of the early cultivars T-21 and Pusa ageti for up to 7 weeks. These flower-removal treatments resulted in a protraction of the flowering period and a marked delay in leaf senescence compared with the controls. The maturity of the plants was consequently delayed in proportion to the length of the flowering period; the total shoot dry weight increased significantly as a result of this longer period of growth before harvest (Fig. 10). In cv. T-21 none of the flower-removal treatments had any significant effect on pod number per plant or yield, but in cv. Pusa ageti deflowering resulted in a significant decline in both pod number and yield (Fig. 10).

Thus in the indeterminate cv. T-21 the plants were able to compensate completely for the flower removal, but this was not the case in cv. Pusa ageti, which is morphologically determinate. The possible disadvantage of the determinate habit in this respect is not owing to an inability to go on producing flowers, since the racemes continue to grow in an indeterminate manner (see PPR 1975/6 Section II.2); this continued production of flowers is indicated by the data on the cumulative weight of flowers removed from plants of cv. Pusa ageti (Table 18). Nor did the determinate habit ~~did not~~ seem to put cv. Pusa ageti at a disadvantage compared with cv. T-21 in the maintenance of leaf area during the flowering period (Table 19). In both the cultivars leaf area, leaf number and leaf dry weight declined to a comparable extent, and in both the decline was less after protracted flower-removal. So the reasons for the differences in the ability to compensate for flower removal are not clear.

The deflowering treatments had little effect on seed number per pod in either cultivar, but in both there was a significant increase in 100 seed weight after flower-removal for 7 weeks, both in insect-damaged pods and in undamaged pods. Possibly this increase occurred

Table 18., Total dry weight of flowers removed from cvs. Pusa ageti and T-21 by deflowering from 1-7 weeks.

Cultivar	Mean total dry weight of flowers removed (g/plant) Deflowering Period (weeks)				
	1	2	3	4	7
Pusa ageti	1.1	4.0	8.3	11.1	16.3
T-21	1.3	6.9	11.5	-	19.2

Table 19. Effects of flower removal on leaf fall (estimated from the number of leaf scars per plant) leaf area, leaf number and lamina dry weight in cvs. Pusa ageti and T-21.

Treatment	Date	No. of fallen leaves/ plant	Leaf No./ plant	Leaf area/ plant (cm^2)	Lamina dry wt./ plant (g)
PUSA AGETI					
Control	20-9-76	17	114	3479	19.7
Control	15-10-76	53	84	2448	11.2
Flower removal until 6-10-76	15-10-76	44	95	2800	13.6
Control	10-11-76	93	36	731	4.5
Flower removal until 6-10-76	10-11-76	91	25	273	2.2
Flower removal until 3-11-76	10-11-76	80	65	1460	8.5
T-21					
Control	21-9-76	19	193	3795	14.7
Control	16-10-76	106	183	2149	13.6
Flower removal until 7-10-76	16-10-76	61	180	3069	13.6
Control	15-11-76	164	47	392	2.4
Flower removal until 7-10-76	15-11-76	220	26	273	1.6
Flower removal until 3-11-76	15-11-76	82	87	1076	5.8

because the plants benefitted from the rainfall in early November at the beginning of their pod-filling period, a few days after the last flower-removal treatment.

All three medium-duration cultivars were able to compensate completely in pod number and yield after flower removal for as long as 5 weeks (Fig. 11). Indeed in cv. ICP-6997 there was a significant increase in yield after deflowering for 2 and 3 weeks and in cv. HY-3A after deflowering for 3 weeks. We cannot suggest any explanation for these increases.

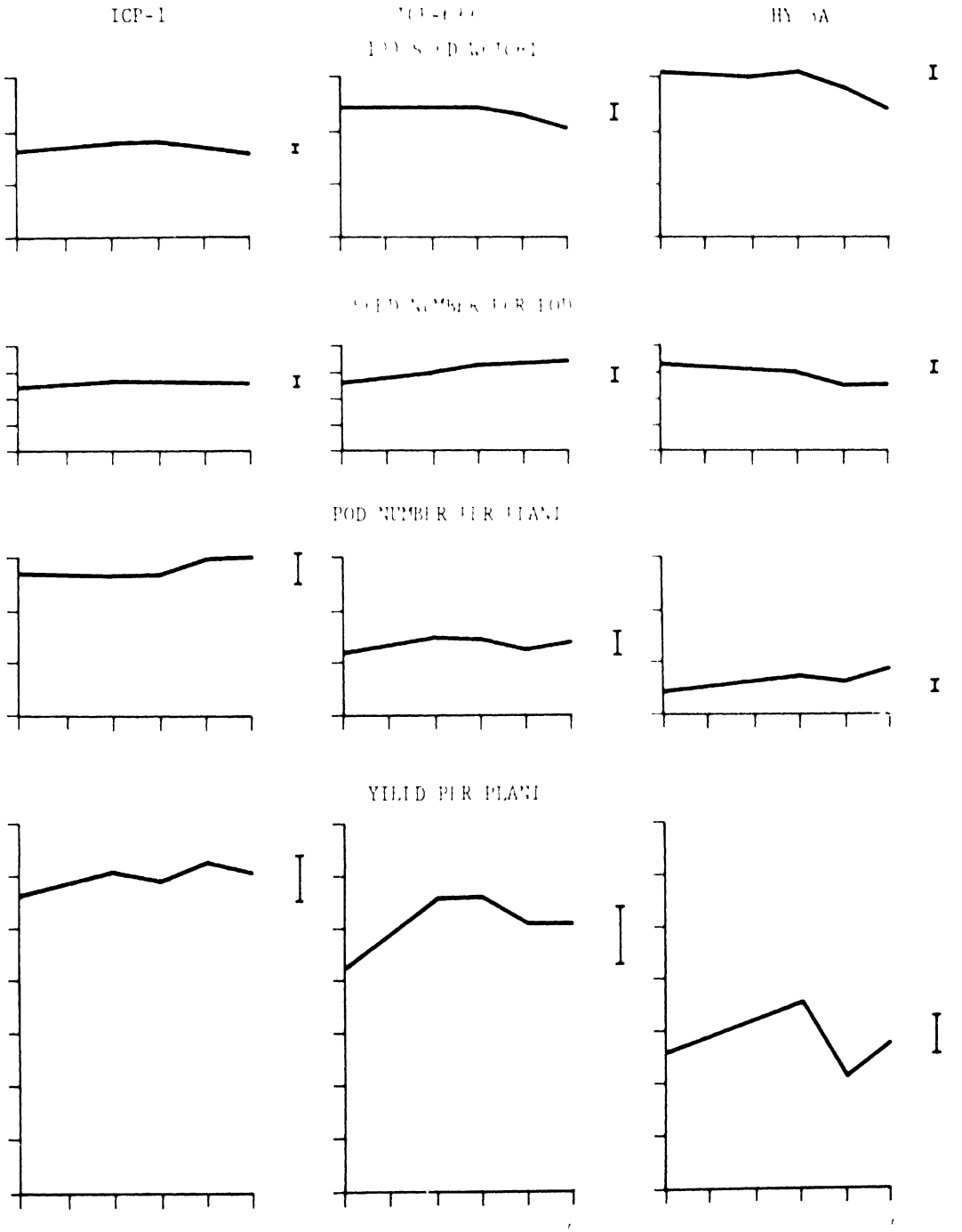
There was no significant effect of the deflowering treatments on total dry weight of the shoot system at harvest in cvs. ICP-1 and ICP-6997. In cv. HY-3A after two, three and five weeks' deflowering, there was a significant increase (from 71 g in controls to 86, 91 and 91 g respectively). However there may also have been an increase in the total dry weight produced by cvs. ICP-1 and ICP-6997 if the flowers were taken into account (see Table 20). The quantity removed after 5 weeks was considerable, especially in ICP-1 (19.4 g/plant). However these figures cannot simply be added to the total shoot weights at harvest to indicate the total amount of dry matter produced, because fallen flowers and fallen leaves would also have to be included in the sum, and we do not have these data.

Table 20. Total dry weight of flowers removed from cvs. ICP-1, ICP-6997 and HY-3A by deflowering from 2-5 weeks.

Mean total dry weight of flowers removed (g/plant)

Cultivar	Deflowering Period (weeks)			
	2	3	4	5
ICP-1	8.6	11.8	14.2	19.4
ICP-6997	7.2	8.1	8.0	11.9
HY-3A	2.9	4.3	5.7	6.5

FIGURE 11 EFFECT OF FLOWER REMOVAL FOR DIFFERENT LENGTHS OF TIME ON YIELD PER PLANT AND YIELD COMPONENTS LSD (5%) ARE INDICATED BY BARS



In cvs. ICP-6997 and HY-3A, the 100-seed weights declined significantly after the longer periods of deflowering and there was a similar tendency in cv. ICP-1 (Fig. 11). These declines may reflect an increasing water stress to which these later-maturing plants may have been exposed, analogous to the lower 100-seed weights observed in the second harvest of seeds, especially when the second harvests were delayed by ratooning (see Section IV.2).

We do not know why the seed number per pod increased significantly in ICP-6997 and decreased significantly in HY-3A(Fig.11) after longer periods of deflowering.

At the time of flowering began, all cultivars contained considerable amounts of starch in their stems, as revealed by the blue-black colour of the cut stems after treatment with iodine solution. In the controls the amount of starch declined during the reproductive phase until little or none was detectable at the time of harvest. In the plants from which flowers were removed, the stems contained large amounts of starch. These results indicate that pod development leads to a mobilization of the starch reserves from the stems. The deflowered plants, especially of cvs. T-21 and Pusa ageti, also developed a deeper pigmentation of the stems, suggesting that the formation of the anthocyanin pigment was enhanced when competition for assimilates by developing pods was prevented.

In cv. ICP-1 the nitrogen percentages in the stems, leaves and seeds of control plants and plants from which flowers had been removed for 5 weeks were compared at the time of harvest. The nitrogen percentage in the seeds was the same in both, but the deflowered plants had a lower percentage of nitrogen in the stems and branches.

The remarkable ability of the plants of all the indeterminate cultivars to compensate completely after all pod-set was prevented for up to 5-7 weeks seems likely to be an important factor in their response to pest attack. These deflowering experiments probably provide a direct indication of the response of the plants to pests which attack flowers or young pods, leading to flower and pod abortion. We cannot be sure that the same type of compensation occurs when pests (such as pod borers and the pod fly) damage seeds within pods which have already set. However it is clear that the ability of the plants to compensate is asymmetric in time: early damage can be compensated for by the setting of pods from later-formed flowers; but damage occurring later in the reproductive phase is unlikely to be compensated for in this way. This suggests that if limited quantities of insecticide are to be used, protection of the plants in the later part of the reproductive phase is likely to be more important than in the earlier period, soon after flowering begins.

II.3

EFFECTS OF FLOWER REMOVAL FROM DIFFERENT PARTS OF THE PLANTS

In these experiments flowers were repeatedly removed from different parts of the plants while in other parts of the same plants, flower and pod development were not disturbed. The purpose of these investigations was to find out to what extent local disturbances of pod-set could be compensated for elsewhere in the plants.

1. Flower removal from alternate nodes:

In the first type of experiment, carried out with cvs. T-21 and ICP-1, pod development was prevented at alternate flowering nodes on the branches and main stem. Thus on every branch and on the main stem the number of nodes at which pod-set could take place was reduced by one half. In cv. T-21 this had no effect on the yield (Table 21) or on components of yield. Thus there was a complete compensation which involved setting on average twice as many pods as usual at the alternate nodes from which flowers were not removed. This indicates that the number of flowering sites within the branches and main stem was not limiting yield in cv. T-21.

Table 21. Effects of flower removal from alternate flowering nodes or alternate branches of pigeonpeas on yield (g/plant).

Cultivar	Control	Flower removal from alternate nodes	Flower removal from alternate branches	LSD(5%)
T-21	14.3	14.3	7.1	3.98
ICP-1	28.4	23.5	29.0	4.06
ICP-6997	21.3	-	28.9	5.18
HY-3A	13.1	-	8.8	3.97

In cv. ICP-1 there was a significant reduction in yield (Table 21). However, the fact that the reduction of the number of flowering sites by 50% resulted in a decrease in yield of only 17% again indicates that the normal number of flowering sites was superoptimal, but not so much so as in cv. T-21. The decreased yield in cv. ICP-1 was owing to a lower pod number per plant. There was a significant increase in 100-seed weight (from 8.3 to 8.9 g).

2. Flower removal from alternate branches:

This treatment had no effect on yield or yield components in cv. ICP-1. In cv. ICP-6997 there was a significant increase in yield (Table 21) as a result of a greater number of pods per plant. By contrast, in cvs. T-21 and HY-3A yield was significantly reduced (Table 21) as were the number of seeds per pod (from 3.1 to 2.3 in cv. T-21 and from 3.3 to 2.9 in cv. HY-3A). These lower yields were associated with a lower pod number per plant which was significant at the 5% level in cv. T-21.

Tentative interpretations of these results are as follows:

(a) In cv. ICP-1 assimilates may have moved freely from the deflowered branches to the branches on which pod-set was taking place, resulting in additional pod-set which compensated completely for the lack of pod-set on the other branches.

We cannot think of a plausible explanation for the increased yield in cv. ICP-6997.

(b) The halving of the yield by the deflowering of alternate branches in cv. T-21 cannot be explained as a consequence of the reduction of the number of pod-bearing nodes, because of 50% reduction brought about by deflowering alternate nodes had no effect on yield (Table 21). Perhaps in this cultivar translocation did not take place readily between the branches. This conclusion is also suggested by the effect of defoliating alternate branches of this cultivar (see Section II.6).

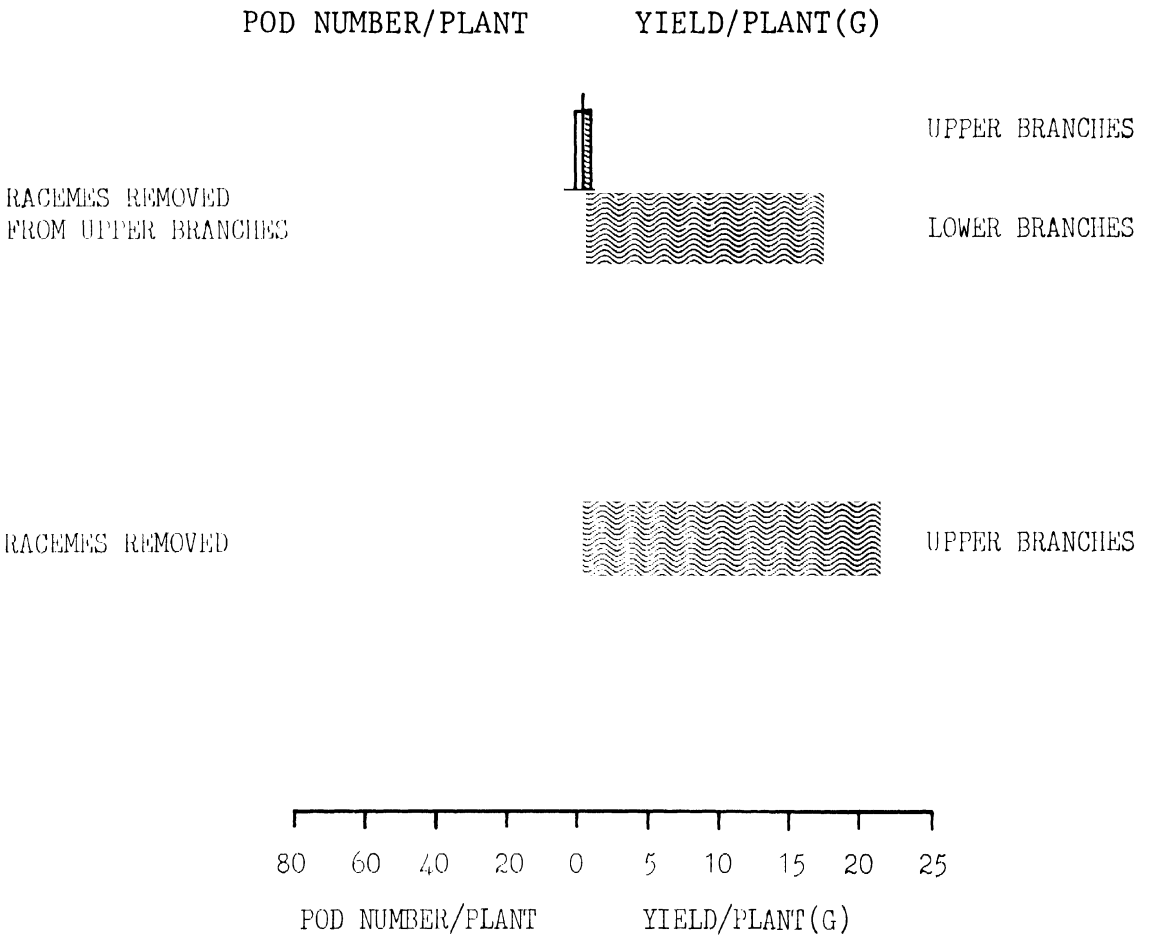
(c) The yield reduction in cv. HY-3A could reflect an inability to compensate because of the limited number of pod-bearing sites; in this cultivar fewer flowers are produced than in the others, and the flowering period is shorter.

3. Flower removal from upper or lower branches:

In cv. ICP-1 racemes were repeatedly removed from all the upper branches (including the main stem) or from all the lower branches.

The yield and pod numbers produced in the upper and lower parts of these plants are shown in Fig.12. It is clear that the prevention of pod set on the lower branches resulted in a compensatory setting of pods on the upper branches, and vice versa.

FIGURE 12. EFFECT OF RACEME REMOVAL FROM UPPER OR LOWER BRANCHES OF CV ICP-1 ON POD NUMBER AND YIELD (CONTROL PLANTS PRODUCED 135 PODS/ PLANT AND YIELDED 28.4g/ PLANT).



II.4

EFFECTS OF DIFFERENT DEGREES OF DEFOLIATION

In the early cultivar T-21, the removal of one third or one half of the total number of leaves throughout the reproductive phase resulted in only slight and statistically insignificant declines in yield (Fig. 13). Even the removal of two thirds or three quarters of the leaves resulted in yield reductions of less than 50%. There was, however, a drastic decline in yield after total defoliation.

The only yield component which was significantly reduced by the higher degrees of defoliation was pod number per plant (Fig. 13). Seed number per pod was unaffected. Total defoliation resulted in a significant increase in 100-seed weight.

In cv. ICP-1 there was no significant effect of defoliation up to 67% on yield or pod number per plant (Fig. 14). Even 75% defoliation resulted in a decline in yield of less than 25%. The number of seeds per pod was significantly reduced compared with the control by the 75% and the total defoliation treatments; the latter treatment also resulted in a significant decline in 100-seed weight.

In cvs. ICP-6997 and HY-3A only 50% and 100% defoliations were carried out. In both cultivars 50% defoliation led to only a slight and statistically insignificant decline in yield and pod number per plant (Table 22). However, the yield and pod number per plant were greatly reduced by total defoliation; there was also a considerable reduction in 100-seed weight in both cultivars and in cv. HY-3A there was a significant reduction in seed number per pod (Table 22).

The 50% and 100% defoliation treatments did not have any clear effect on the percentage of nitrogen in the stems, leaves or seeds at the time of harvest except in the case of cv. T-21 where the nitrogen percentage in the seeds increased after 100% defoliation (Table 22a).

Discussion

In all four cultivars, half or more than half of the leaves could be removed throughout the reproductive phase with only a slight and statistically insignificant effect on yield and yield components. This indicates that leaf area was not a limiting factor for pod set and yield.

The simplest interpretation of these results is that the photosynthetic functioning of the leaves was limited by some other factor; removal of half the leaves resulted in a greater supply of this factor

FIGURE 13. EFFECTS OF DIFFERENT DEGREES OF DEFOLIATION ON YIELD AND YIELD COMPONENTS OF CV T-21. LSD^{S} (5%) ARE INDICATED BY BARS.

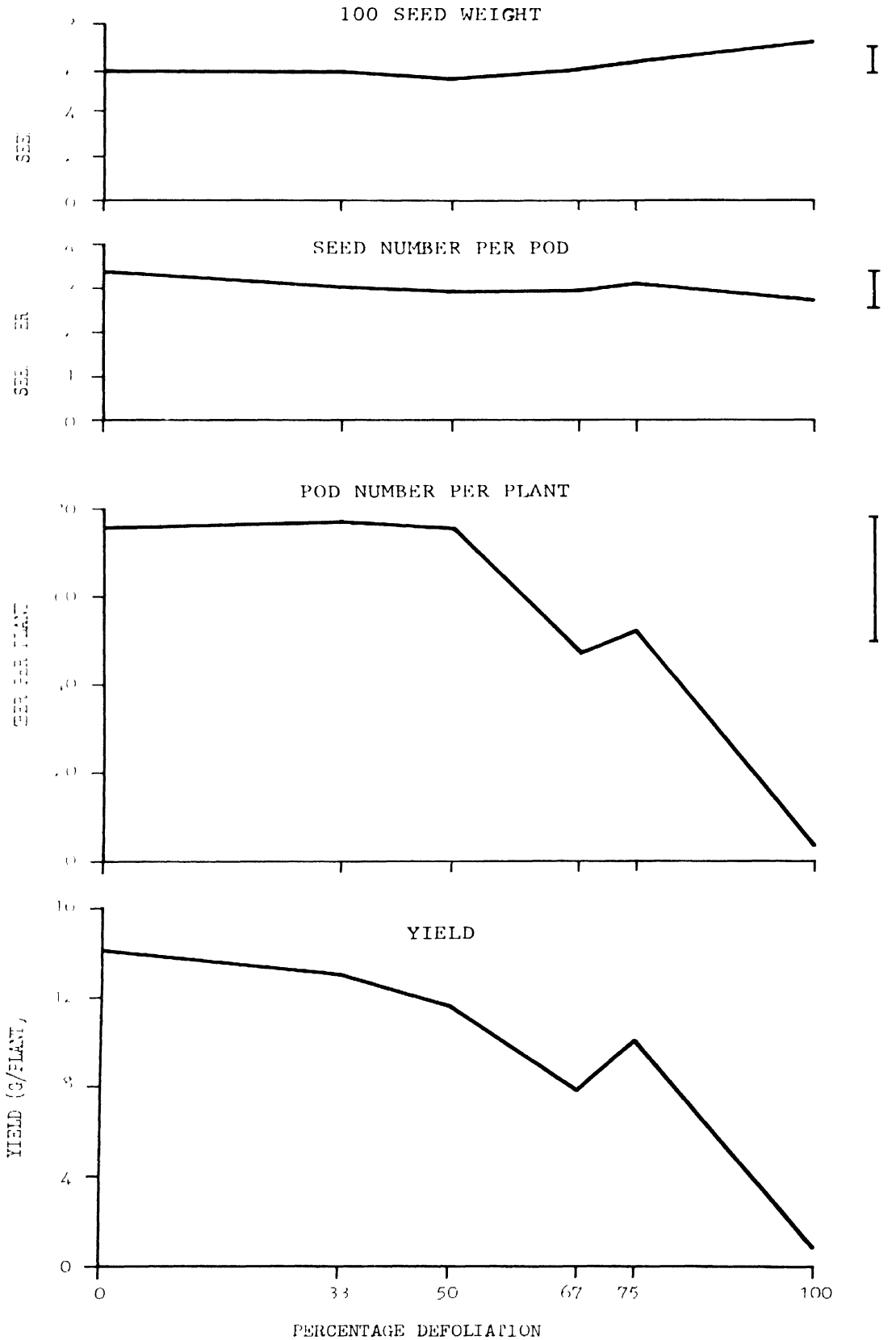


FIGURE 14 EFFECTS OF DIFFERENT DEGREES OF DEFOLIATION ON YIELD AND YIELD COMPONENTS OF CV ICP-1 $LSD^{S}(5\%)$ ARE INDICATED BY BARS

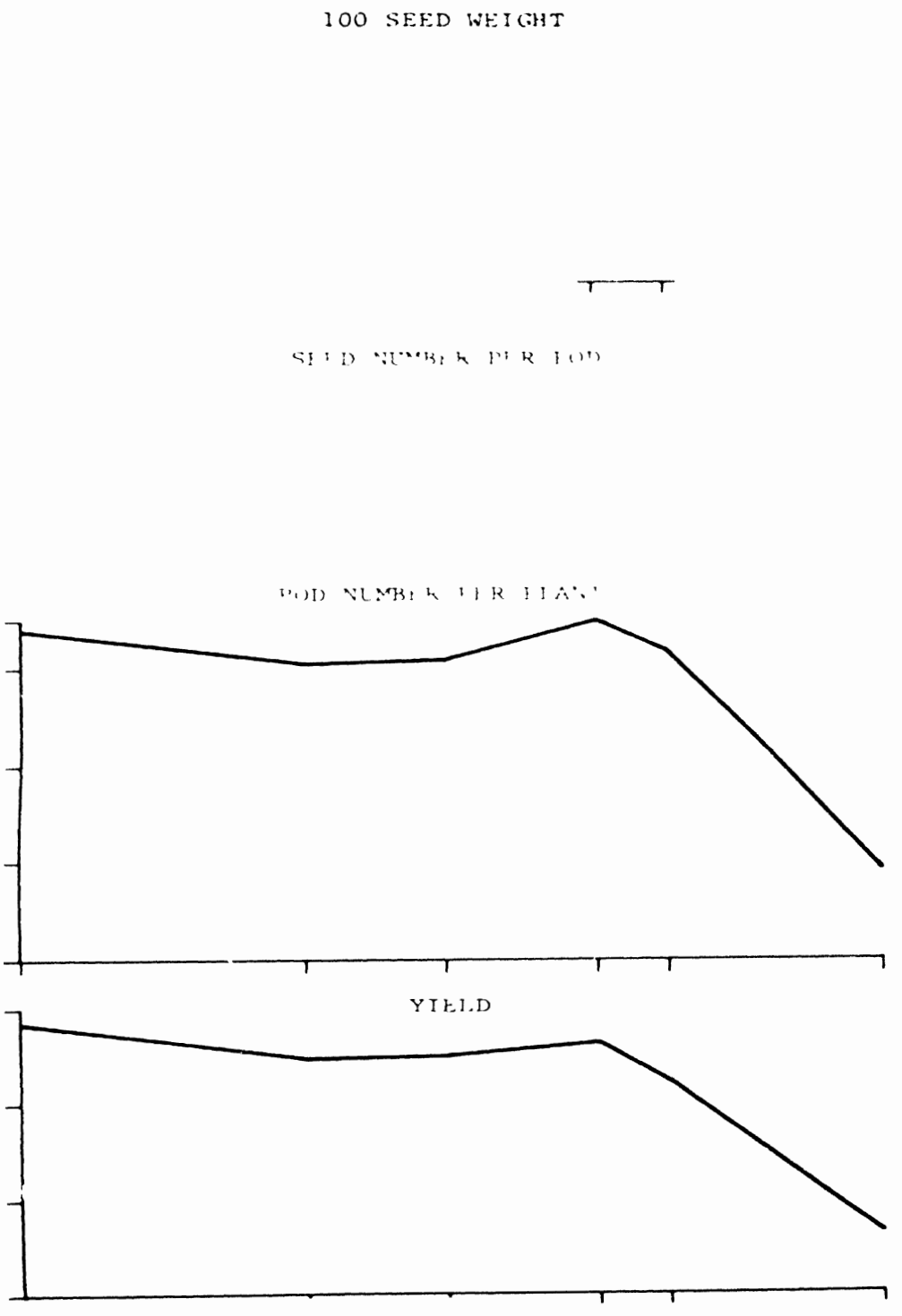


Table 22. Effect of 50% and 100% defoliation throughout the reproductive period on yield and yield components of cvs. ICP-6997 and HY-3A.

Treatments	Yield/ plant (g)	Pod Number/ plant	Seeds/ pod	100-seed weight (g)
Cv. ICP-6997				
Control	21.3	61.2	2.8	12.4
50% defoliation	18.6	55.0	2.9	11.6
100% defoliation	2.8	11.0	2.8	8.8
LSD (5%)	3.60	15.34	0.3 (NS)	1.28
Cv. HY-3A				
Control	13.1	23.9	3.4	16.5
50% defoliation	10.6	19.8	3.3	16.6
100% defoliation	1.7	5.3	3.0	10.8
LSD (5%)	3.69	7.46	0.27	1.01

Table 22a. Effect of 50% and 100% defoliation throughout the reproductive phase on nitrogen percentage in different plant parts at the time of harvest

Cultivar	Plant parts	NITROGEN PERCENTAGE		
		Control	50% defoliation	100% defoliation
T-21	Main stem	0.57	0.61	0.59
	Branches	0.76	0.80	0.64
	Leaves	3.24	3.31	-
	Seeds	3.37	3.67	4.62
ICP-1	Main stem	0.66	0.48	0.49
	Branches	0.82	0.83	1.11
	Leaves	3.08	3.40	-
	Seeds	3.49	3.16	3.17
ICP-6997	Main stem	0.78	0.73	0.82
	Branches	1.12	0.81	0.80
	Leaves	3.28	2.95	-
	Seeds	3.44	3.33	3.65
HY-3A	Main stem	0.60	0.64	0.59
	Branches	0.76	0.83	0.81
	Leaves	-	2.97	-
	Seeds	3.22	3.15	3.14

to the remaining leaves and a consequent increase in photosynthetic activity which more or less compensated for the loss of half of the leaf-area. This factor was probably not light, for two reasons. (a) The LAIs were not particularly high. At the time of flowering the LAIs were as follows: T-21, 2.5; ICP-1, 3.1; ICP-6997, 2.4; HY-3A, 1.7; and the LAIs declined during the reproductive phase. Hence there would have been little mutual shading and it unlikely that the plants were suffering from a limitation of light. (b) The results obtained this year differ from those obtained last year in similar experiments, where defoliation treatments of even 33% brought about more or less proportional reductions in yield (see PPR 1975/6 Section II.1).

The differences between the response to defoliation in the two years in cv. T-21 can be seen in Fig.15. It is noticeable that the yield levels of the controls were higher in 1975 than in 1976.

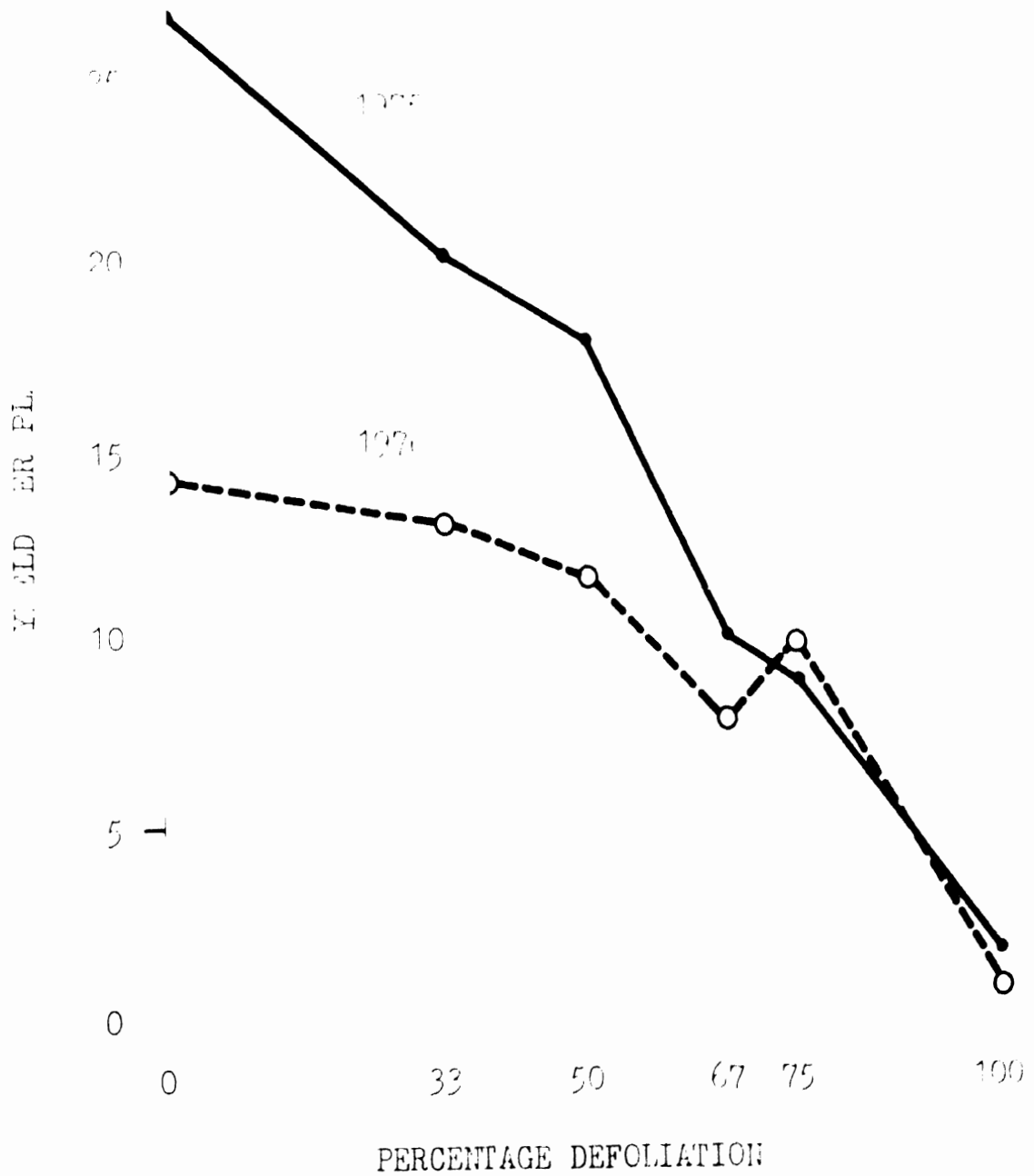
In general, the overall yields, of pigeonpeas were considerably lower in 1976/7 than in 1975/6. These differences most likely seems to have been a consequence of the different amounts of water available to the plants. In 1975 the monsoon ended unusually late, half-way through the reproductive phase of the medium cultivars; whereas in 1976 the monsoon ended unusually early. Rainfall data for the two years are shown in Table 23.

Table 23. Monthly rainfall at ICRISAT farm (Hyderabad) from May to December in 1975 and 1976 and the long-term average for 30 years at Hyderabad.

RAINFALL (mm)

Month	Y E A R		
	30 years average	1975	1976
May	26.5	1.7	22.4
June	115.5	98.4	86.0
July	171.5	195.2	215.8
August	156.0	139.4	314.5
September	181.0	422.3	74.0
October	67.0	173.5	0.6
November	23.5	15.0	29.7
December	6.0	0	0
Total	747.0	1,045.5	743.0

FIGURE 15. EFFECT OF DIFFERENT DEGREES OF DEFOLIATION ON THE YIELD PER PLANT OF CV T-21 IN THE KHARIF SEASONS OF 1975 AND 1976



Hence the factor which was limiting the photosynthetic effectiveness of the leaves in this year's experiments was probably water. Also in 1974/5 we found that plants which were probably under moisture stress (long duration cultivars grown in the kharif season and short-duration cultivars grown in the off-season which were maturing in the summer) showed no reduction in yield after 50% defoliation throughout the reproductive period (see PPR 1974/5 Chapter V and PPR 1975/6 section II.1, Discussion).

A possible explanation is as follows: when the plants are under water stress, the stomata of the leaves may close around or before the middle of the day as a result of failure of the water-supply to the leaves to keep pace with transpiration. As the water stress increases, the stomata may close earlier and earlier, resulting in less and less photosynthesis being carried out per day. Under such conditions, the removal of some of the leaves is likely to result in a greater availability of water to the remaining leaves, and hence to a delay in the closure of their stomata and an increase in the amount of photosynthetic assimilation. The extent to which a reduction in leaf number per plant could be compensated for by increased photosynthesis in the remaining leaves would be a function of the severity of the moisture stress.

It seems probable that the greater effects of 67% and 75% defoliation in reducing yield in cv. ICP-1 (Fig.14) compared with cv. T-21 (Fig. 13) may have been because T-21 is an early-duration cultivar which matured sooner after the end of the monsoon and probably experienced less moisture stress as a consequence.

The decreased 100-seed weight in cvs. ICP-1, ICP-6997 and HY-3A after total defoliation indicates that slightly more pods were set than the plants were capable of sustaining to the normal degree of development. However the reverse seems to have been true of cv. T-21 where the 100 seed weight increased after total defoliation (Fig. 13) and there was also an increase in the nitrogen percentage in the seeds (Table 22a). This suggests that in control plants of cv. T-21, 100-seed weight may be reduced because slightly more pods are set than can be fully filled. And indeed this is the only cultivar examined so far where there was some indication from the relative weights of earlier and later formed pods that pod-set may not be the primary limitation on yield (see Section III.3).

II.5

EFFECTS OF TOTAL DEFOLIATION AT DIFFERENT STAGES OF THE REPRODUCTIVE PHASE

Total defoliation of the plants from the time of flowering onwards had a drastic yield-reducing effect, largely through a reduction in pod number per plant, but in all the medium duration cultivars there was also a reduction in 100 seed weight (Fig. 14, Table 22).

In cv. ICP-1 the effects of starting the total defoliation treatment 3 weeks and 5 weeks after the beginning of the reproductive phase were investigated.

The treatment beginning 5 weeks after flowering had only very slight effects on yield and yield components which were statistically insignificant (Table 24). This indicates that the leaves made little contribution to pod-setting or pod-filling after this time.

When the total defoliation was begun 3 weeks after flowering the pod number per plant was reduced by 36% compared with the control, but the yield was reduced by 47%. The results suggest that many of the pods were set and that their seed number was established before the defoliation began, but that they could not be filled properly after the defoliation treatment; hence the 100 seed weight declined (Table 24).

Table 24. Effects of 100% defoliation at the time of flowering and 3 and 5 weeks after flowering on yield and yield components of cv. ICP-1.

Treatments	Yield/ plant(g)	Pod Number/ plant	Seeds/ pod	100 seed weight (g)
Control	28.4	135.2	2.5	8.3
Defoliation at flowering	6.3	37.3	2.2	7.3
Defoliation 3 weeks later	15.1	86.5	2.6	6.9
Defoliation 5 weeks later	25.9	110.8	2.8	8.5
LSD (5%)	3 68	25.91	0.33	0.44

The declines in the 100 seed weights after these defoliation treatments indicate that more pods were set than the plants were capable of filling to the normal extent. By contrast, in untreated plants, even late-formed pods were fully filled (Sections III.3 & IV.4) indicating that their yield was primarily limited by pod-set rather than the ability of the plants to fill the pods.

II.6

EFFECTS OF THE DEFOLIATION OF ALTERNATE BRANCHES

In this treatment alternate branches and the main stems of the plants were defoliated. The total leaf area would therefore on average have been reduced by over 50%. In all cultivars, this treatment resulted in lower yields than 50% defoliation by alternate leaf removal (Table 25) but the differences were not significant at the 5% level. We have already suggested (in Section II.4 above) that 50% defoliation had only a small effect on yield or yield components because the remaining leaves received a larger supply of water and were thus able to compensate photosynthetically for the reduced leaf area. The same reasoning would apply whether the leaves were removed from alternate nodes or alternate branches. The tendency for alternate branch defoliation to give greater yield reductions than alternate node defoliation may be because the reduction in leaf area was greater; it might also reflect a tendency for translocation to occur less readily between branches than within branches. However we do not have data on the relative proportion of the total yield which was borne on defoliated and undefoliated branches. Last year we found that when alternate nodes were defoliated within branches, pod set occurred equally well at nodes with and without leaves, indicating a very effective translocation from node to node within the branches (see PPR 1975/6 Section II.1).

Table 25. Effect of defoliation of alternate nodes and alternate branches throughout the reproductive phase on yield of pigeonpea cultivars.

Cultivar	Control	Defoliation of alternate nodes	Defoliation of alternate branches	LSD(5%)
T-21	14.1	11.5	9.1	3.10
ICP-1	28.4	24.9	24.0	3.68
ICP-6997	21.3	18.6	15.5	3.60
HY-3A	13.1	10.6	10.5	3.69

II.7

EFFECTS OF THE REMOVAL OF SENESCENT LEAVES

The removal of senescent leaves throughout the reproductive phase had no significant effect on yield, except in the case of Pusa ageti where there was a slight reduction which was just significant at the 5% level (Table 26).

The weights of leaves removed per plant and the amounts of translocatable nitrogen in them are shown in Table 27. The amount of nitrogen removed in this way was small and could have accounted for only 3-13% of the nitrogen in the grain of the plants. Therefore, the removal of senescent leaves would not have been expected to have much effect on yield by reducing the amount of nitrogen remobilized from the leaves to the grain. The removal of half or more of the green leaves would have had a much greater effect in reducing the amount of remobilizable nitrogen in the plant but also had little effect on yield (Section II.4), suggesting that nitrogen supply was not the primary limiting factor for yield.

In cv. ICP-1 the control and treated plants were analysed for nitrogen at the time of harvest. The removal of senescent leaves was found to have had little or no effect on the percentage of nitrogen in the stems, remaining leaves or seeds.

Senescent leaves are known to produce a number of hormones including auxin, abscisic acid and ethylene. It seemed possible that these might move back into the plants and affect their development; hence senescent leaf removal might prevent these hormonal effects. However we found little or no effects of this treatment on yield or yield components, so the hormonal effects of senescent leaves do not seem to have been important in this connection, if indeed the senescent leaves had any hormonal effects upon the plants at all.

Table 26. Effect of the removal of senescent leaves throughout the reproductive phase on yield of pigeonpea cultivars.

Cultivar	Yield (g/plant) Control	Senescent leaves removed	LSD(5%)
Pusa ageti	17.1	14.2	2.88
T-21	14.1	13.9	3.10
ICP-1	28.4	26.3	3.68
ICP-6997	21.3	18.9	3.60
HY-3A	13.1	13.1	3.69

Table 27. Total weight of senescent leaves removed from plants of pigeonpea cultivars, percentage of nitrogen in senescent and fallen leaves, the calculated amount of translocatable nitrogen in senescent leaves and this amount of nitrogen removed expressed as a percentage of the amount of nitrogen in the grain of control plants.

Cultivar	Weight of senescent leaves removed (g/plant)	N% in senescent leaves	N% in fallen leaves	Nitrogen removed in senescent leaves/ plant (mg)	Amount of N removed as % of N in grain
Pusa ageti	5.27	2.30	1.45*	45	8.7
T-21	3.84	2.05	1.45*	23	4.9
ICP-1	7.09	1.96	1.45	36	3.5
ICP-6997	7.87	2.13	1.36	60	7.9
HY-3A	8.86	2.25	1.56	61	12.9

* Value assumed on the basis of mean nitrogen percentage in fallen leaves of other cultivars.

II.8

EFFECTS OF APICAL BUD REMOVAL

Last year we attempted to alter the balance between vegetative growth and reproductive growth during the reproductive phase of an indeterminate cultivar by removing the apical buds of the main stem and branches at the time of flowering. This treatment reduced the growth of the treated branches but had no significant effect on yield or yield components (see PPR 1975/6 Section 11.3). This year a similar experiment was carried out with the indeterminate cultivar T-21. The apical buds of the main stems and branches were removed either at the time of flower bud initiation or at the time that 50% of the plants began to flower. Neither treatment had any significant effect on yield, harvest index, or total dry weight at the time of harvest (Table 28). In early cultivars such as T-21 over 75% of the total stem weight is added after flower bud initiation and a considerable number of new primary and secondary branches are produced (see PPR 1974/5 Table 3). The lack of effect of the apical bud removal treatments on the partitioning of dry matter between vegetative and reproductive growth can probably be explained in terms of a compensatory increase in the growth of new branches which were formed during the reproductive phase.

Table 28. Effect of apical bud removal at the time of flower bud initiation and at the time of flowering on harvest index, yield and total dry matter produced by cv. T-21 grown on red soil.

Treatments	Harvest index (%)	Yield/ plant (g)	Total dry wt./plant (g)
Control	28.4	14.6	51.1
Removal of apical meristem at flower bud initiation stage	24.9	12.4	49.7
Removal of apical meristem at 50% flowering stage	25.2	14.6	5B.9
LSD (5%)	6.1 (NS)	2.96(NS)	10.97(NS)
CV%	13.5	12.4	11.9

II.9

EFFECTS OF SHADING THROUGHOUT THE REPRODUCTIVE PHASE ON RABI PIGEONPEAS

Last year it was found that the shading of chickpeas throughout the reproductive period resulted in delayed senescence and maturity of the plants. With 50% shading, the yield was significantly higher than the unshaded control (CPR 1975/6 Section II.3). Similar results were obtained again this year (see CPR 1976/7).

We carried out a similar shading trial with pigeonpeas grown in the rabi season in order to compare the effects of shading on the two crops when they were both grown under the same climatic conditions and both dependent entirely on residual soil moisture.

Methods

The trial was conducted in a split-plot design (3 replications) with cultivars C-11, ICP-1 and NP(WR)-15 in the main plots and shading treatments in sub-plots. These treatments were: control (no shade), 50% shade (white cotton cloth intercepting 50% photosynthetically active radiation (PAR) at noon) and 80% shade (thick white cotton cloth intercepting 80% PAR at noon). The sub-plot size was 3 x 4 m.

The trial was sown on 20-10-76 with spacing of 40 x 10 cms and the shades were fixed horizontally above the plots (supported by a frame-work of horizontal wires 1 M above ground level attached to bamboo stakes) when 50% of the plants had begun to flower. These dates were: C-11, 9-1-77; ICP-1, 13-1-77; NP(WR)-15, 25-1-77. Unfortunately some of the cloth shades on ICP-1 and C-11 were stolen on 17-1-77. A complete set of the remaining shades were placed over the ICP-1 plots on 18-1-77 and C-11 remained unshaded until 25-1-77 when new shades were obtained.

Cvs. ICP-1 and C-11 were harvested on 15-3-77 and cv. NP(WR)-15 on 1-4-77.

The shaded areas were open at the sides and there was a free circulation of air beneath the shades. The day-time air temperature and also the minimum temperatures at night in the shaded plots were the same or slightly higher (1^{o} - 2^{o}C) than in the unshaded control plots.

Results and discussion

The shading treatments caused some delay in the senescence of the leaves, but the senescence-retarding effects of shading were far

less spectacular than those observed with chickpeas.

In all cultivars the 80% shading treatment led to a substantial and significant decrease in yield (Table 29). The 50% shading treatment also led to a significant reduction in the mean yield. The reduction with both shading treatments was greatest in cv. NP(WR)-15. The plants of this cultivar were taller than those of the other two and the shoot tips in some cases grew up against the shade. It is therefore possible that the greater reduction in yield by shading with this cultivar was owing in part to mechanical effects. However, when the yield data were analysed statistically excluding this cultivar the reduction in yield by 50% shading was still significant at the 5% level (Table 29).

Table 29. Effects of shading throughout the reproductive period on yield of pigeonpeas grown in the rabi season.

Yield (kg/ha)

	CULTIVAR			Mean (for all cvs.)	Mean for cvs. C-11 and ICP-1 only
	C-11	ICP-1	NP(WR)-15		
Control (No shade)	1198	1125	1047	1123	1162
50% Shade	1068	976	967	937	1022
80% Shade	732	680	493	635	706
Mean	1000	927	769		

LSD (5%)

For cultivars	:	230
For treatments (means of all cultivars	:	131
For treatments (means of cvs. C-11 and ICP-1 only)	:	118
For shading treatments within a cultivar	:	227
For comparison of means between groups	:	259

CV = 14.2%

Both shading treatments also led to reductions in the total dry weight of the shoot system (Table 30). The harvest index was not significantly affected by 50% shading. (The H.I. was 30.8% in controls, 30.3% in 50%-shaded plants) but was reduced by the 80% shading (HI of 25.3% LSD (5%) = 1.71). There was no significant effect of the shading treatments on 100-seed weight or seed number per pod.

The most obvious and straightforward explanation for the growth- and yield-reducing effects of the shades is in terms of reduced photosynthesis (plus a possible mechanical effect of the shades in the case of cv. NP(WR)-15). The effects of the 50% shades may have been small because the high levels of radiation in the rabi season (often 1700-2000 μ Einsteins m^{-2} $sec.^{-1}$ photosynthetically active radiation at noon) may be more than enough to saturate photosynthesis throughout the canopy, and so a 50% reduction may have relatively little effect

On the other hand the shading would have led to less heating of the leaves, and probably also to less transpiration as a consequence. In chickpea the marked senescence-delaying effects of shading and the slightly stimulatory effects of 50% shading on growth and yield may be explicable either in terms of a reduced moisture stress owing to reduced transpiration, and/or to a reduction in direct heat-stress. Unless chickpeas are subject to much more moisture-stress than rabi-grown pigeonpeas, the difference in response to shading between the two crops suggests a differential sensitivity to heat.

The conclusion is supported by the fact that chickpeas are known to be sensitive to high temperatures. For example they cannot be grown successfully, even under irrigation, during the hot season in India; but pigeonpeas can grow under these conditions quite well, indicating that they are much more heat-tolerant than chickpeas.

Table 30. Effect of shading throughout the reproductive phase on total dry weight of the shoot system at harvest of pigeonpeas grown in the rabi season.

Total shoot dry weight (kg/ha)

	CULTIVAR			
	C-11	ICP-1	NP(WR)-15	Mean
Control (No shade)	3630	3392	4089	3704
50% shade	3142	2874	3449	3156
80% shade	2483	2310	3170	2654
Mean	3085	2859	3570	

LSD (5%)

Cultivars	:	1487 (NS)
Shading treatments	:	518
Shading treatments within a cultivar	:	897
Comparison of means between groups	:	1378

CV = 15.9%

III.1

CULTIVARAL DIFFERENCES IN RESPONSE TO ROW SPACING

In a preliminary trial carried out last year we found that there was a large cultivaral difference in response to a range of row spacings (see PPR 1975/6 Section III.5). This year we compared 9 medium and long-duration cultivars grown in the kharif season on both red and black soils. The plantings were made in rows which diverged from a central point ('fan' plantings). We also compared 10 cultivars in 'fan' plantings in the rabi season.

Methods

1. Kharif Plantings:

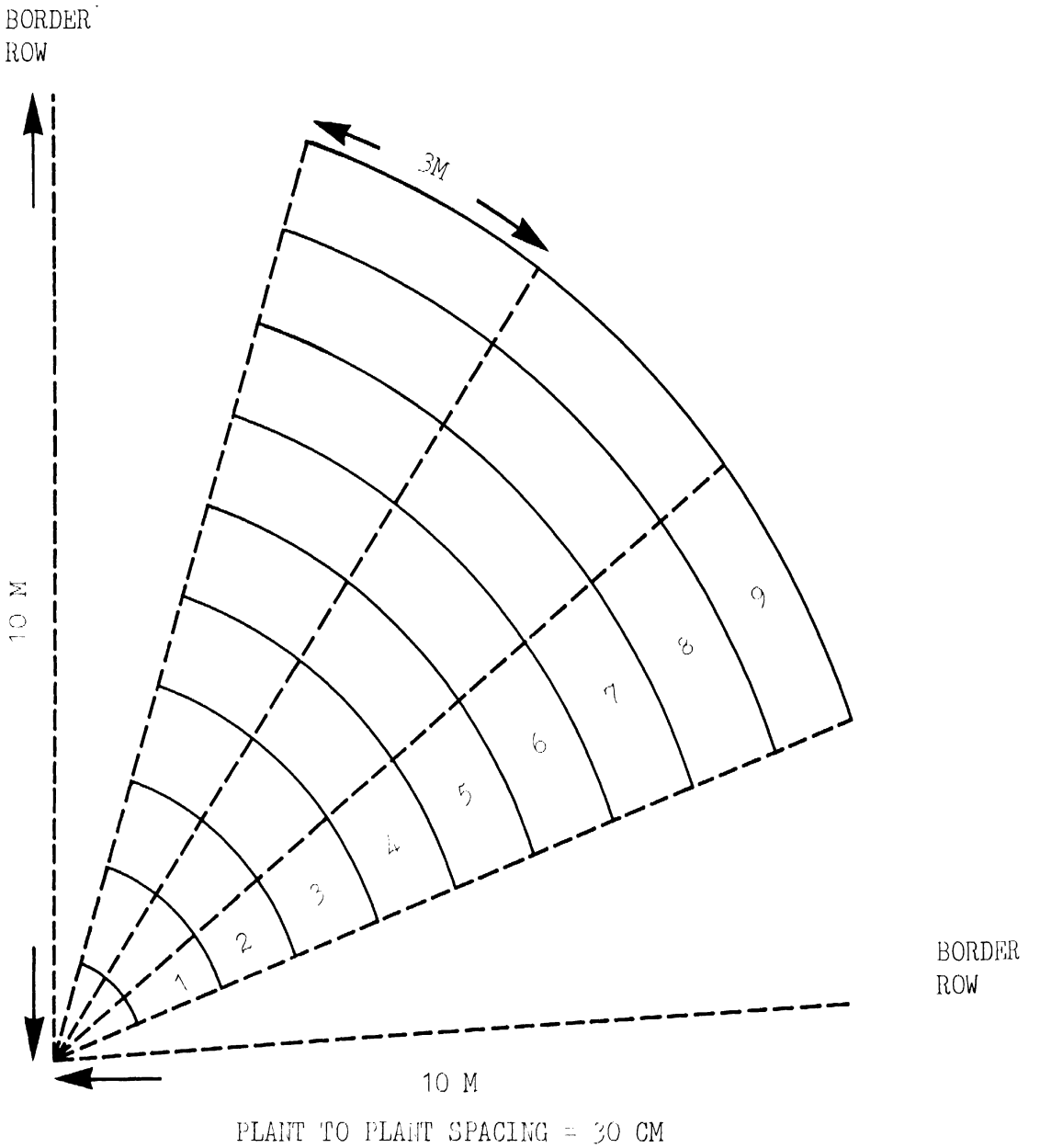
Each 'fan' consisted of six rows 10 m long which diverged from a central point to a row-to-row spacing at the periphery of 3 m. Within the rows the plant-to-plant spacing was 30 cm (see Fig.16). On black soil there were four replicate fans of each cultivar and on red soil three replicates in an RBD. The dates of planting were: black soil (field B5): 8-7-76 and red soil (field R1) 6-7-76.

At the time of harvest the border rows and the last plants in each row were discarded. The fan was divided into ten 1 m sectors; the first 1 m sector was discarded and the remaining sectors were numbered 1-9 from the centre outwards (see Fig.16). The plants were harvested sectorwise and plant numbers, stem weights, yield and yield components were recorded.

The cultivars used and their dates of harvest on black and red soils were as follows:

CULTIVAR	DATE OF HARVEST ON BLACK SOIL	ON RED SOIL
BDN-1	10-12-76	14-12-76
AS-71-37	13-12-76	15-12-76
ICP-1	21-12-76	20-12-76
HY-2	22-12-76	15-12-76
ICP-6997	29-12-76	30-12-76
HY-3A	29-12-76	30-12-76
ICP-7375	1-3-77	7-3-77
ICP-7065	3-3-77	8-3-77
NP(WR)-15	4-3-77	10-3-77

FIGURE 16. DESIGN OF FAN PLANTINGS (KHARIF SEASON)



Because of water-logging damage in red soil field R1 two replicates of cvs. ICP-6997 and HY-3A and one replicate of HY-2 were badly damaged and had to be abandoned. The data for these cultivars are based on the remaining replicates.

The diameters of the main stems of each plant in two rows of each fan were measured 10 cm above ground level with vernier callipers on 10-12-76 on black soil and 12-12-76 on red soil. The mean stem diameter within each sector was calculated from these data.

The extent of canopy cover at a row spacing on 2.6 m was estimated around noon on 29-11-76 in each fan on black soil by stretching a 10 m tape around an arc 9 m from the centre of the fan. The total length of the tape which was shaded was recorded.

2. Rabi Plantings:

The 'fans' planted in the rabi season consisted of 6 divergent rows 5 m long with a row-to-row spacing at the pheriphery of 1 m. The plant to plant spacing within the rows was 10 cm. The seeds were sown on 20-10-76 in black soil (field B5) and lightly irrigated with sprinklers to ensure good germination. Thereafter no irrigation was given. The germination of cv. HY-3A was poor owing to fungal infection of the seeds (a similar problem was encountered with large white-seeded chickpeas in the same field) and this cultivar was resown. There were 4 replications and 10 cultivars were planted in a randomized design.

At the time of harvest the procedure used was similar to that of kharif 'fans'. The fans were divided into 50 cm sectors; the central sector, the border rows and the last plant in each row was discarded. Plant number, stem weights, yield and yield components were recorded at the time of harvest.

The cultivars used and their dates of harvest were as follows:

Cultivars	Date of harvest
ICP-1	9-3-77
C-11	10-3-77
AS 71-37	11-3-77
PM-1	15-3-77
HY-3A	15-3-77
ICP-7065	17-3-77
ICP-7375	18-3-77
GW-3	21-3-77
NP(WR)-15	22-3-77
T-7	23-3-77

Results

1. Kharif plantings

(a) Growth:

There were striking differences between the cultivars in their response to row spacing: some branched and grew more as the row spacing increased, producing a canopy which was almost closed even at 3 m row-to-row spacings; others, especially cv. HY-3A, showed little or no extra growth at the wider row-spacings. Some indication of the extent to which the canopy developed at a wide row-spacing is provided by the data on light interception in Table 31.

Cultivaral differences in the extent to which more branches were produced on the row spacing increased are shown in Fig.17. On both red and black soils cv. ICP-7375 branched most and HY-3A branched least; cvs. ICP-7065, ICP-1, AS-71-77 and BDN-1 responded to the extra space in the wider row-spacings by progressively more branching, but the ability of cvs. HY-2, ICP-6997 and NP(WR)-15 to respond in this way was limited.

The main-stem diameter increased at the wider row spacings (Fig.18) in a manner similar to the branching, but differences between cultivars in this character were less pronounced.

Table 31. Percentage of ground shaded by pigeonpeas grown in fan plantings in zone 8 (row-to-row spacing: 2.6 m). Observations taken on 29th November 1976 around noon.

Cultivar	Percent shade
ICP-7065	77
ICP-7375	73
BDN-1	60
AS-71-37	59
ICP-1	58
NP(WR)-15	57
HY-2	56
ICP-6997	50
HY-3A	38
LSD (5%)	12.9
CV (%)	15.0

FIGURE 17. EFFECT OF SPACING ON BRANCHES/MAIN STEM DRY WEIGHT RATIOS OF PIGEONPEAS GROWN ON RED AND BLACK SOIL (KHARIF 1976-77)

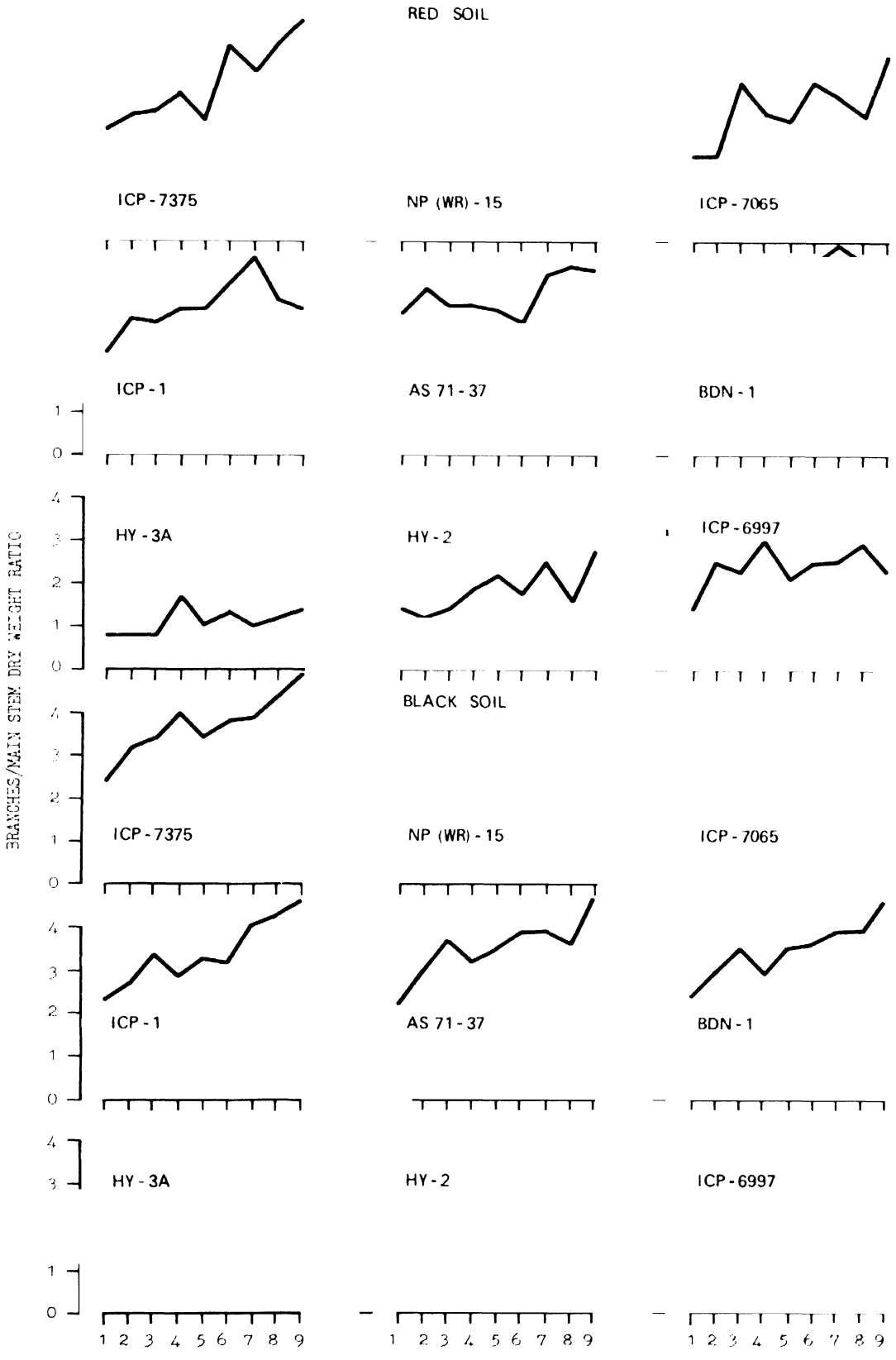
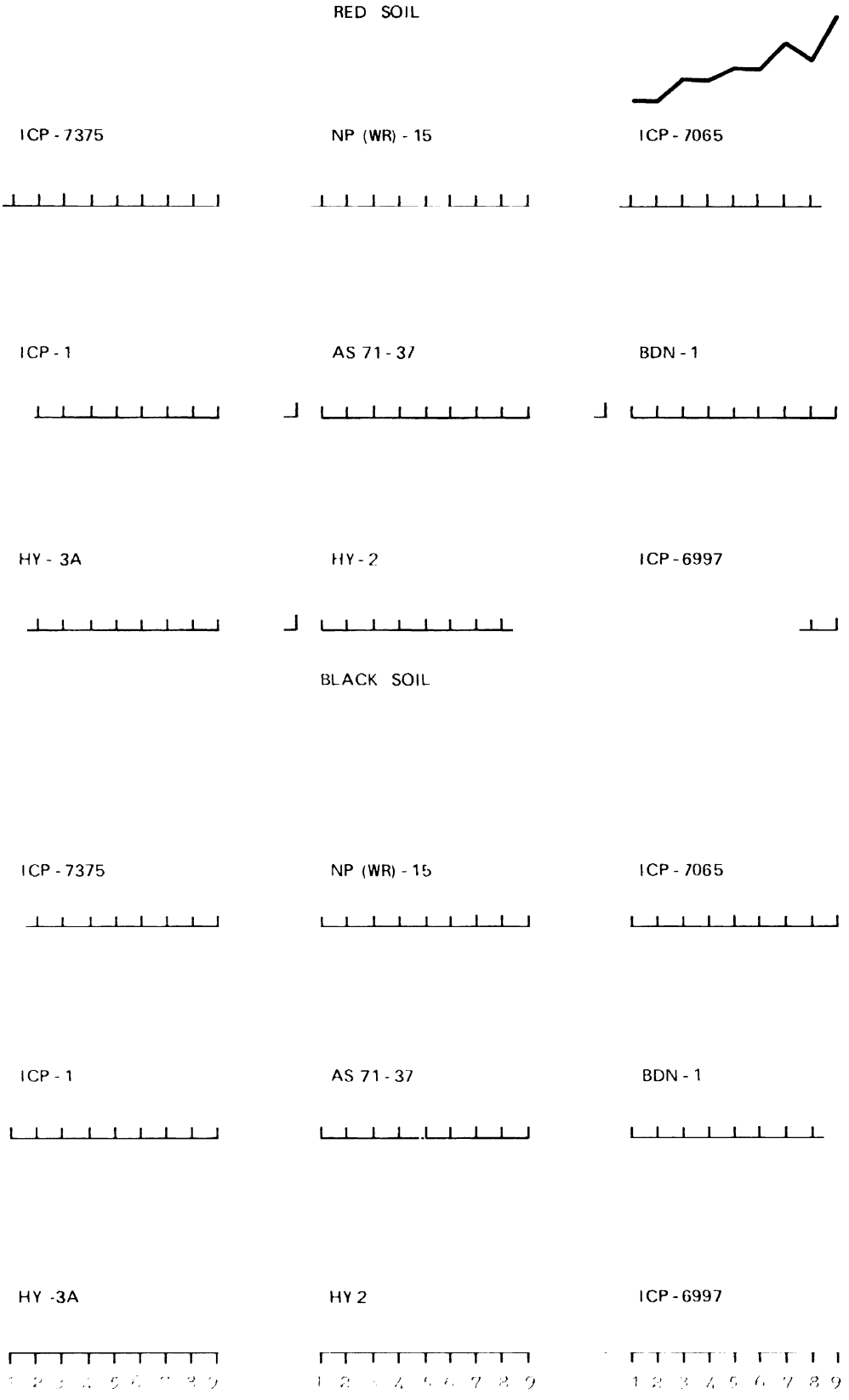


FIGURE 18 . EFFECT OF ROW SPACING ON MAIN STEM DIAMETER OF PIGEONPEAS GROWN ON RED AND BLACK SOIL (KHARIF 1976-77)



(b) Yield:

On both black and red soils most cultivars responded to the wider row spacing by producing progressively more yield per plant (Figs.'19 & 20). However cvs. HY-3A and ICP-6997 reached a maximum 4-6 m from the centre of the fan and thereafter the yield did not increase.

When the grain yields were calculated on the basis of yield per unit area striking differences between black and red soils could be seen (Figs. 21 & 22). On red soil the yield per unit area of all cultivars fell off at the wider row spacings, though in some more steeply than others. By contrast on black soil the yield per unit area remained more or less constant or even increased at the wider row spacings in cvs. ICP-7375, NP(WR)-15, ICP-7065 and ICP-1. There was a tendency for the yield to decline at the wider spacings in cvs. AS-71-37, BDN-1, HY-2 and ICP-6997 and there was a definite and progressive decline in cv. HY-3A.

Although the yields per unit area at the wider row spacings were generally lower on red soil than on black, the reverse was true of the close row spacings. At these closer spacings the total dry weight produced per plant was also greater on red soil than on black.

(c) Harvest index:

On black soil there was a general tendency for the harvest index to rise as the row spacing increased (Fig.23); indeed in some cultivars (NP(WR)-15, ICP-7375, HY-2, ICP-1) it approximately doubled. The exceptions were cvs. HY-3A and ICP-6997 where the harvest index did not increase after sector 5.

On red soil in all cultivars (except ICP-7065) the harvest indices at the closer row-spacings were higher than on black soil (Fig.23). Only in a few cultivars (e.g. ICP-7065, ICP-1) did the harvest index show a clearly defined tendency to increase at the wider spacings; in the others it increased only slightly or remained more or less constant.

(d) Components of yield:

In most cultivars there was little or no effect of row spacing on either red or black soil on seed number per pod (Fig.24). In cv. HY-3A on black soil seed number per pod was depressed at the closer spacings, and there was a similar tendency, though less pronounced in cvs. HY-2 and ICP-6997. Similarly in most cultivars 100-seed weight was not affected by spacing (Fig.25) but again in cv. HY-3A on black

FIGURE 19. EFFECT OF ROW SPACING ON GRAIN YIELD PER PLANT OF PIGEONPEA CULTIVARS GROWN IN BLACK SOIL (KHARIF 1976-77)

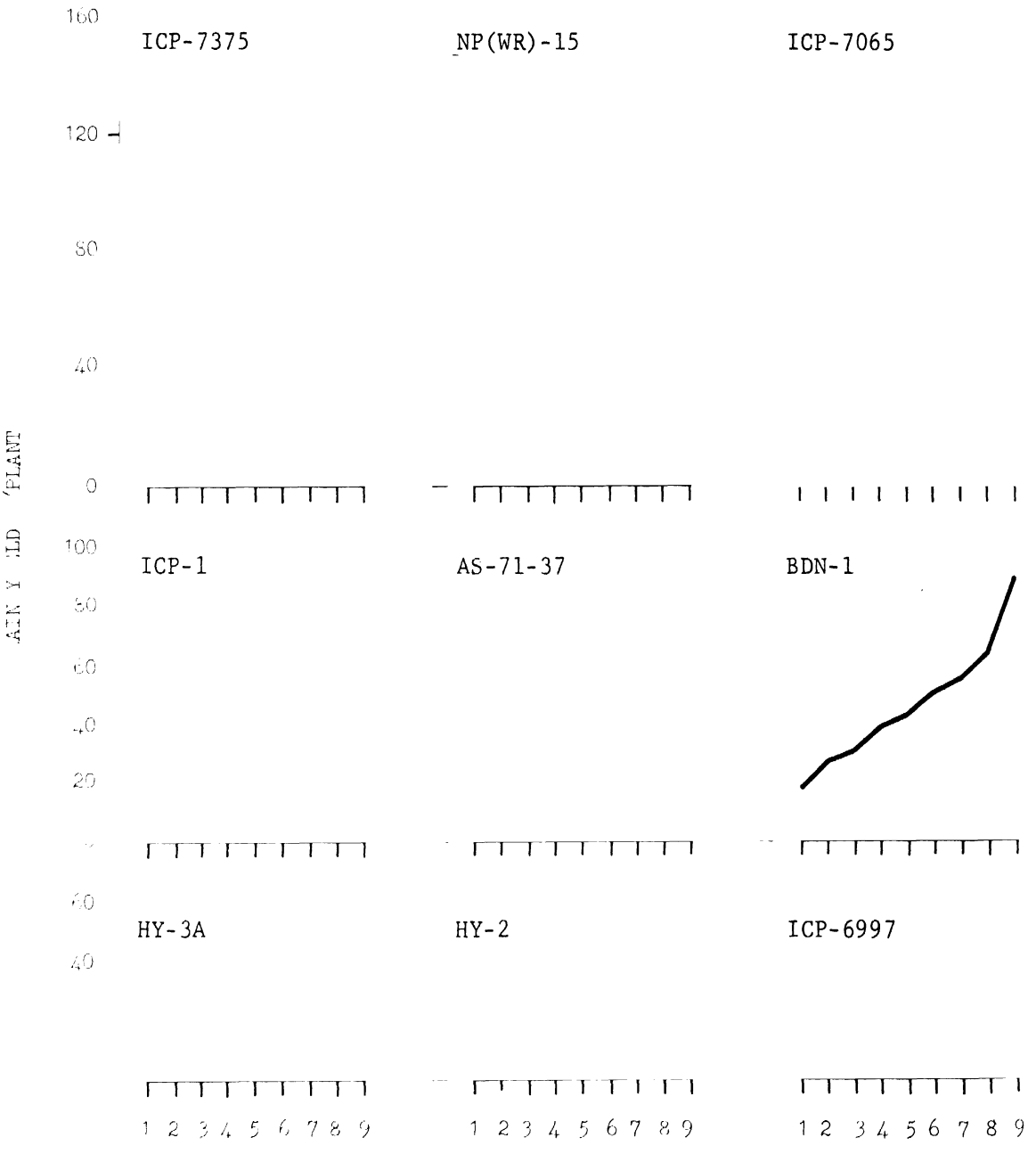


FIGURE 20. EFFECT OF ROW SPACING ON GRAIN YIELD PER PLANT OF PIGEONPEA CULTIVARS GROWN IN RED SOIL (KHARIF 1976-77)

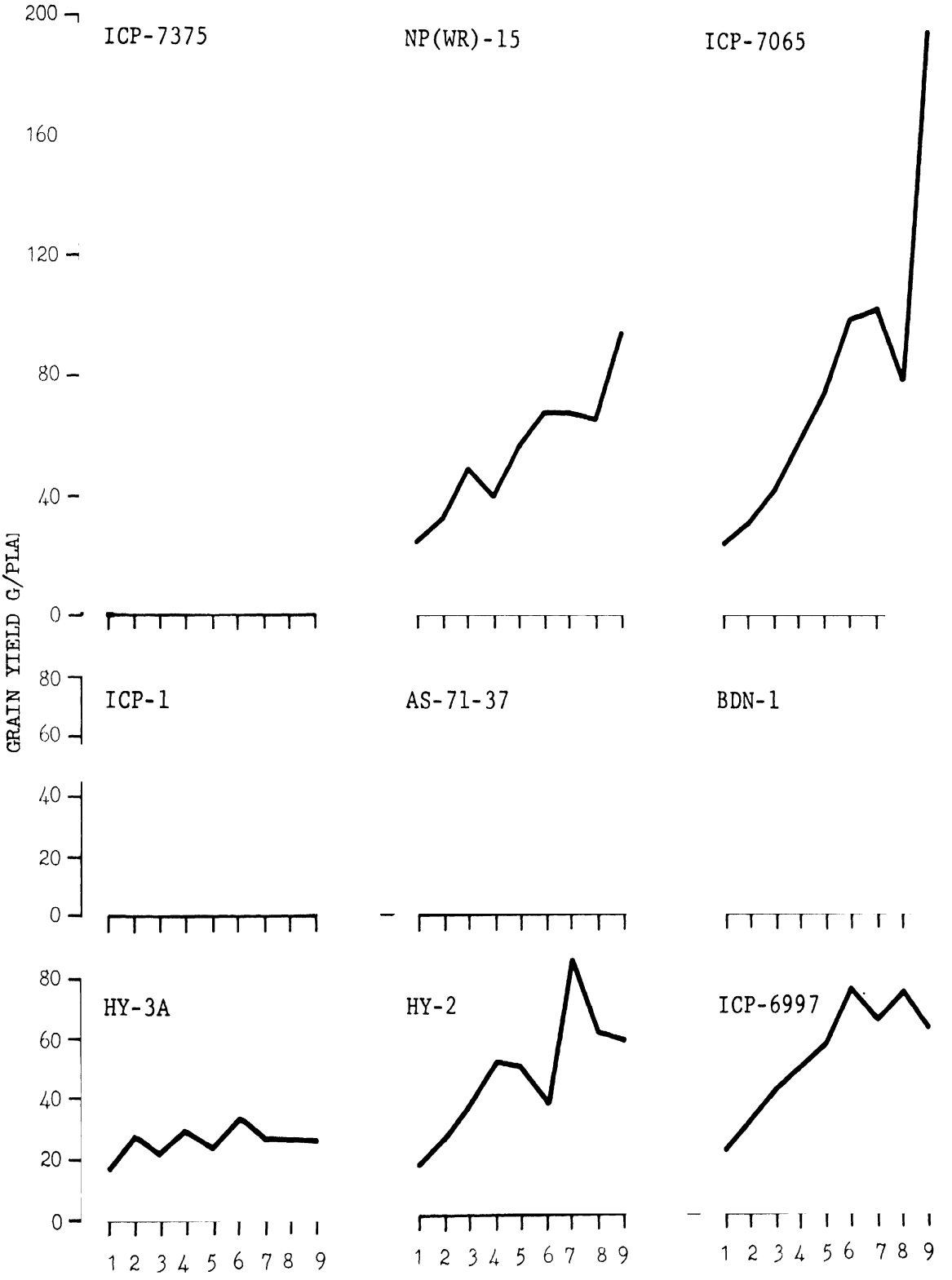


FIGURE 21. EFFECT OF ROW SPACING ON GRAIN YIELD PER UNIT AREA OF PIGEONPEA CULTIVARS GROWN ON BLACK SOIL (KHARIF 1976-77)

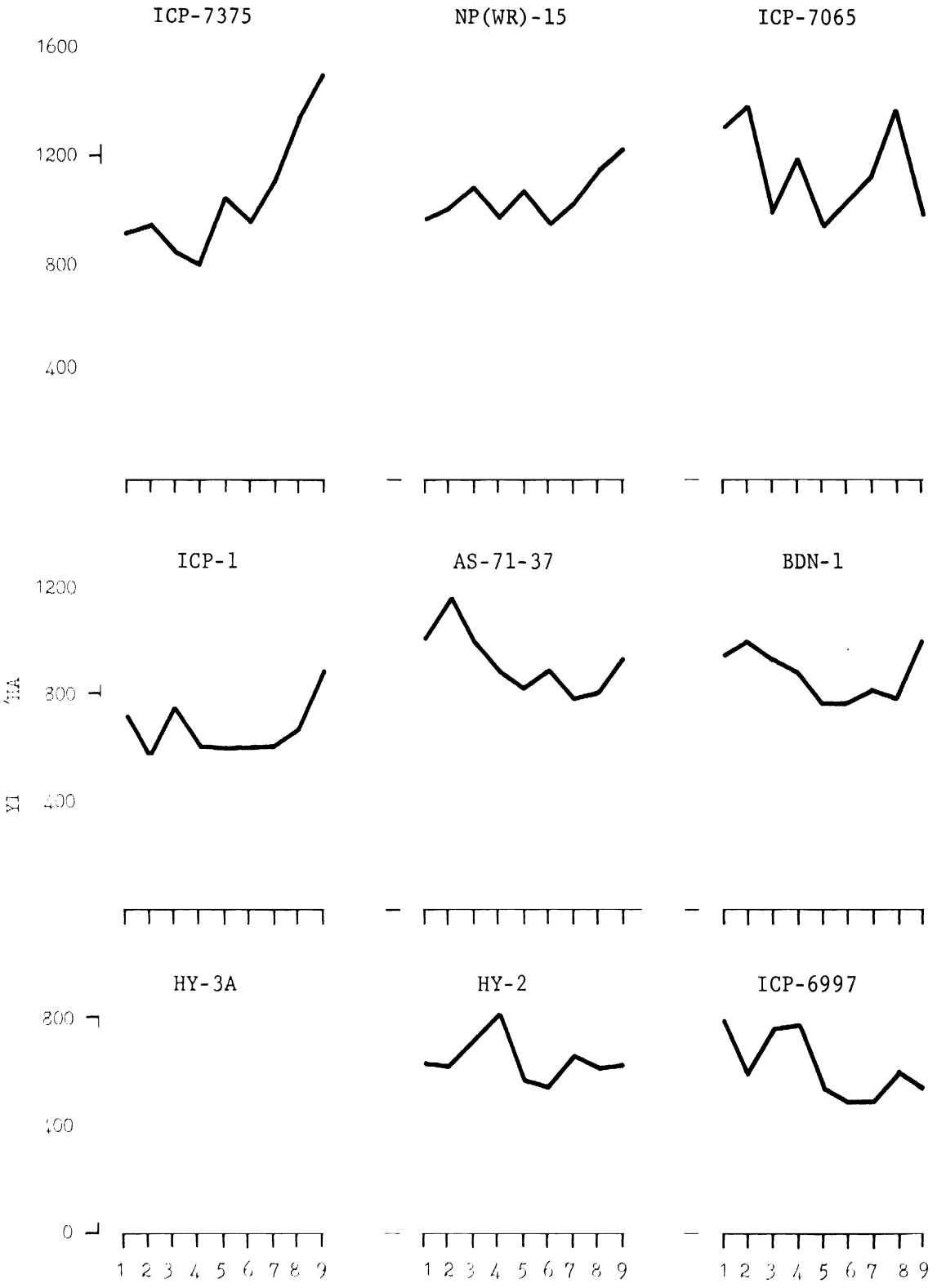


FIGURE 22. EFFECT OF ROW SPACING ON GRAIN YIELD PER UNIT AREA OF PIGEONPEA CULTIVARS GROWN ON RED SOIL (KHARIF 1976-77)

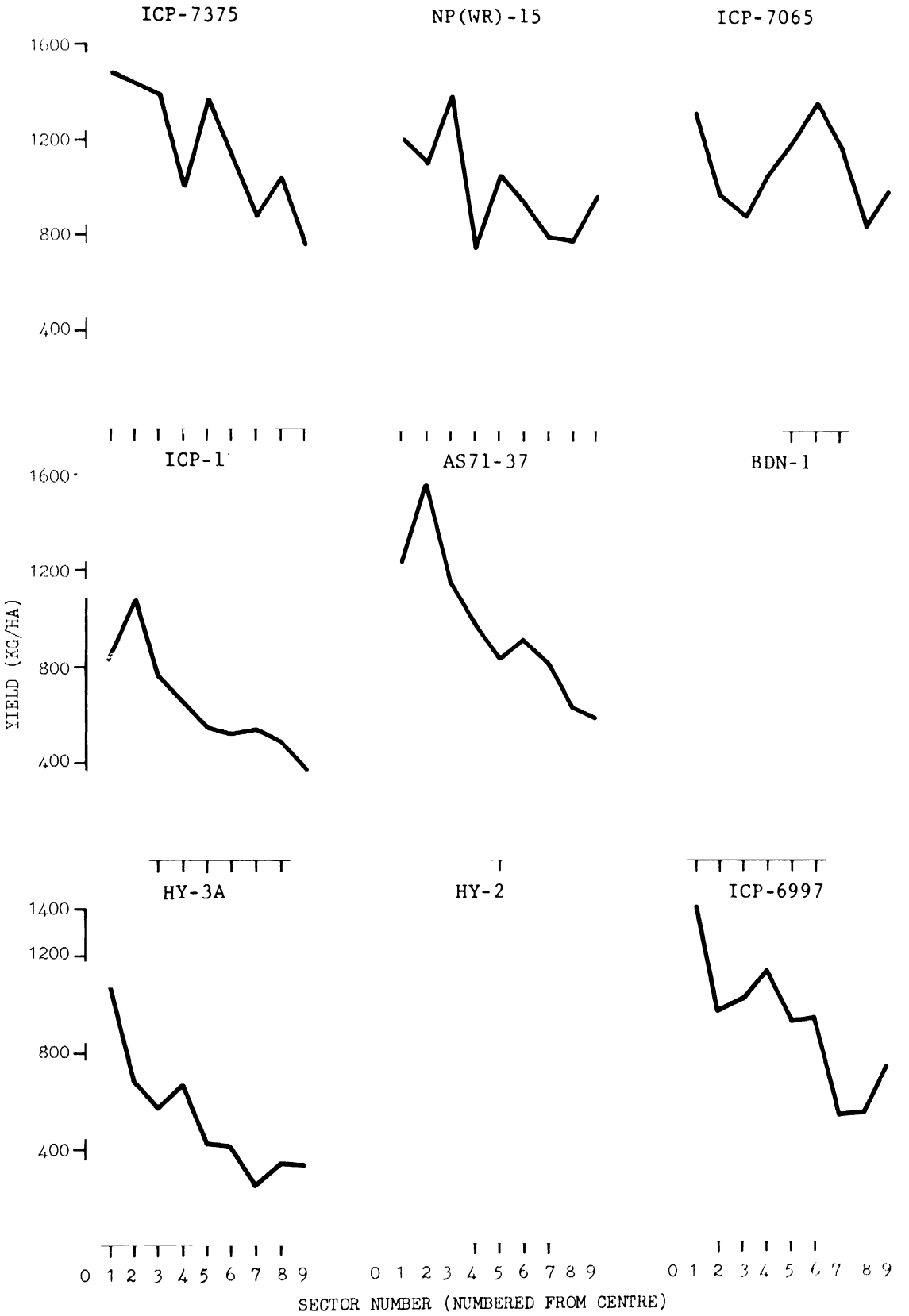


FIG. 23 EFFECT OF ROW SPACING ON HARVEST INDEX OF PIGEONPEA CULTIVARS GROWN IN RED AND BLACK SOILS (KHARIF 1976-77)

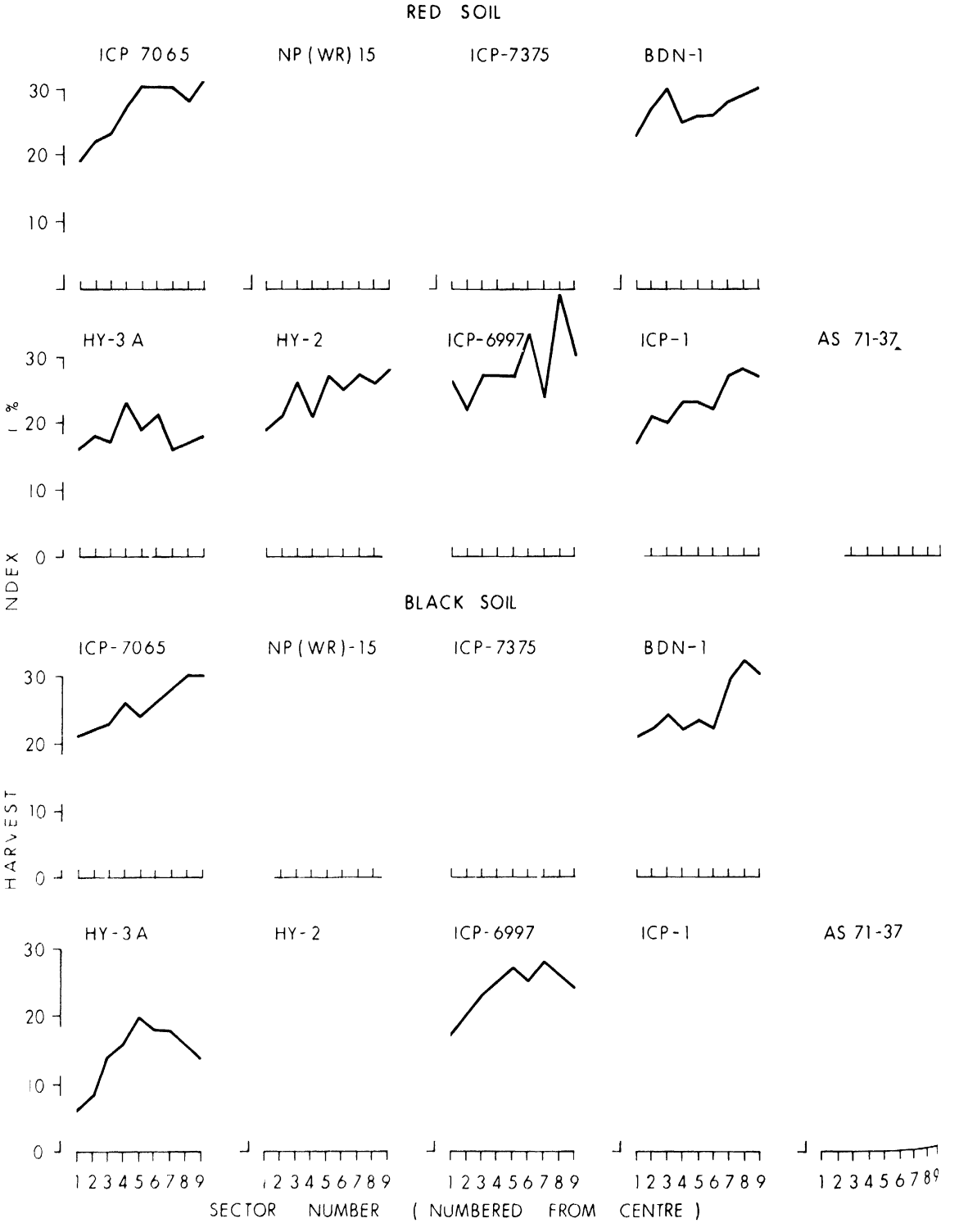


FIGURE 24 . EFFECT OF ROW SPACING ON SEED NUMBER PER POD OF PIGEONPEA CULTIVARS GROWN IN RED AND BLACK SOIL (KHARIF 1976-77)

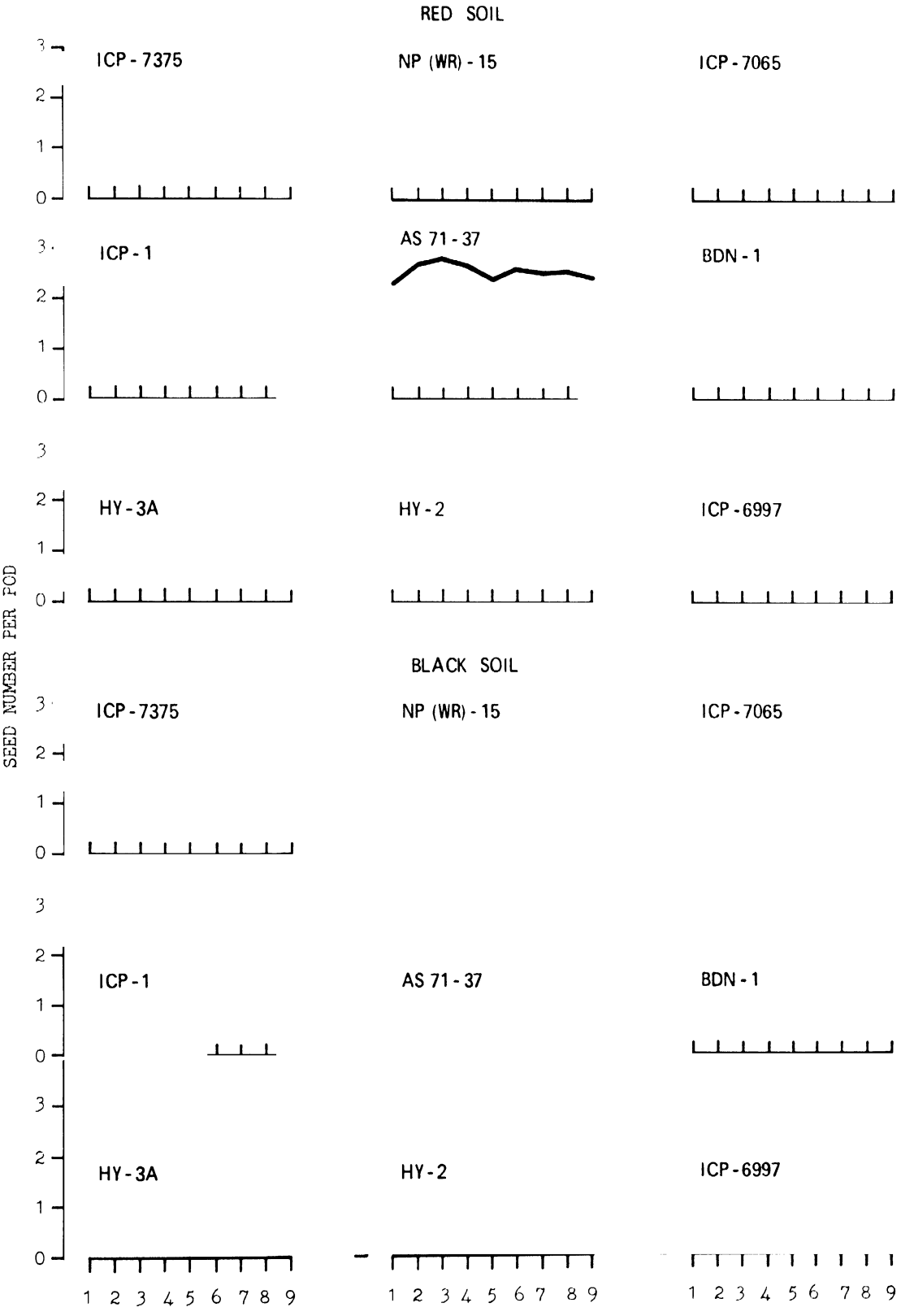
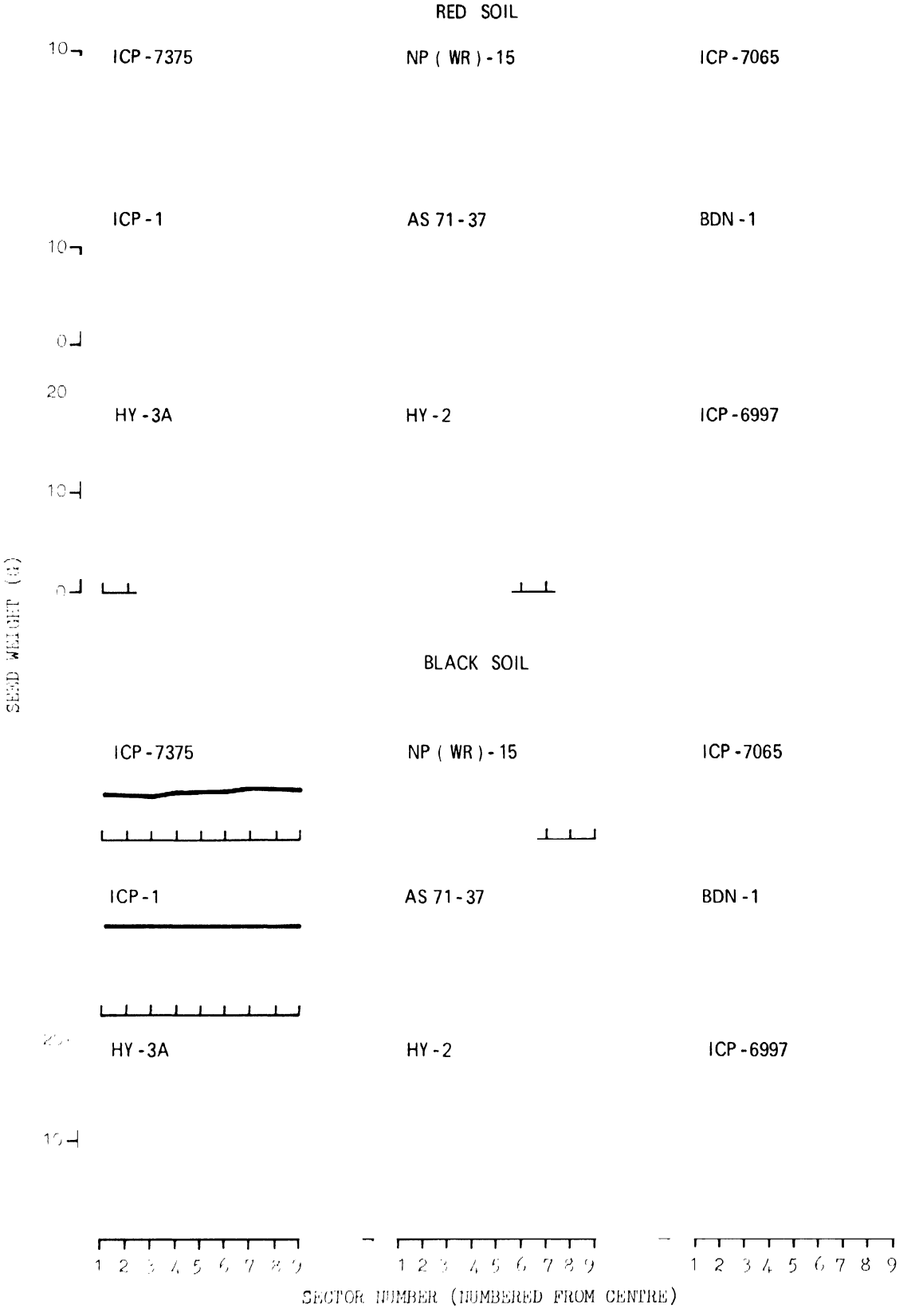


FIGURE 25. EFFECT OF ROW SPACING ON 100 SEED WEIGHT OF PIGEONPEA CULTIVARS GROWN IN RED AND BLACK SOIL (KHARIF 1976-77)



soil the 100-seed weight was lower at the closer spacings. The component of yield which accounted for almost all the yield differences at the different spacings was pod number per plant.

2. Rabi plantings

(a) Growth:

The cultivars differed in the extent to which they were able to fill up the space at the wider spacings. This is reflected in the cultivaral differences in branching (Fig.26); there was most branching in cv. ICP-7375 and least in cv. HY-3A.

(b) Yield:

In all cultivars except cv. HY-3A the yield per plant increased progressively at the wider row-spacings; in HY-3A it reached a plateau at sector 5 (Fig.27). The yield per unit area consequently fell from sector 5 onwards in this cultivar (Fig.28). The other cultivars tended to have highest yields per unit area at the lowest and highest row spacings, probably as a consequence of border effects. Otherwise there was a slight decline or little or no change in the yield per unit area over the range of spacings studied (Fig.28).

(c) Harvest index:

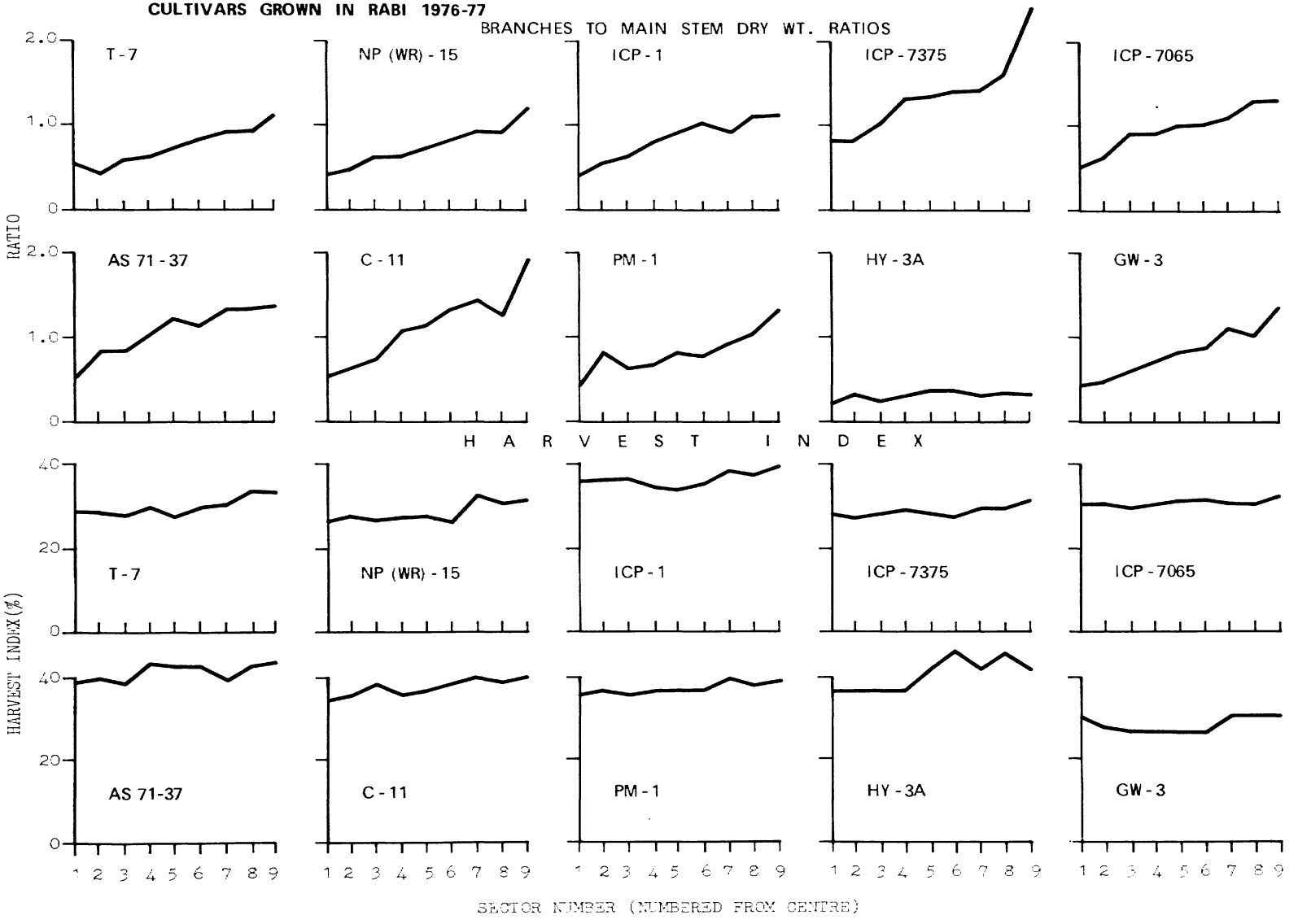
There was little effect of row spacing on harvest index although in some cultivars (e.g. T-7, NP(WR)-15, C-11 HY-3A) there was a tendency for HI to increase at wider spacings (Fig.26). On the whole the harvest indices were higher than those in the kharif season: for example that of rabi ICP-1 was around 35% whereas in the kharif the maximum HI was 28% (Fig.23).

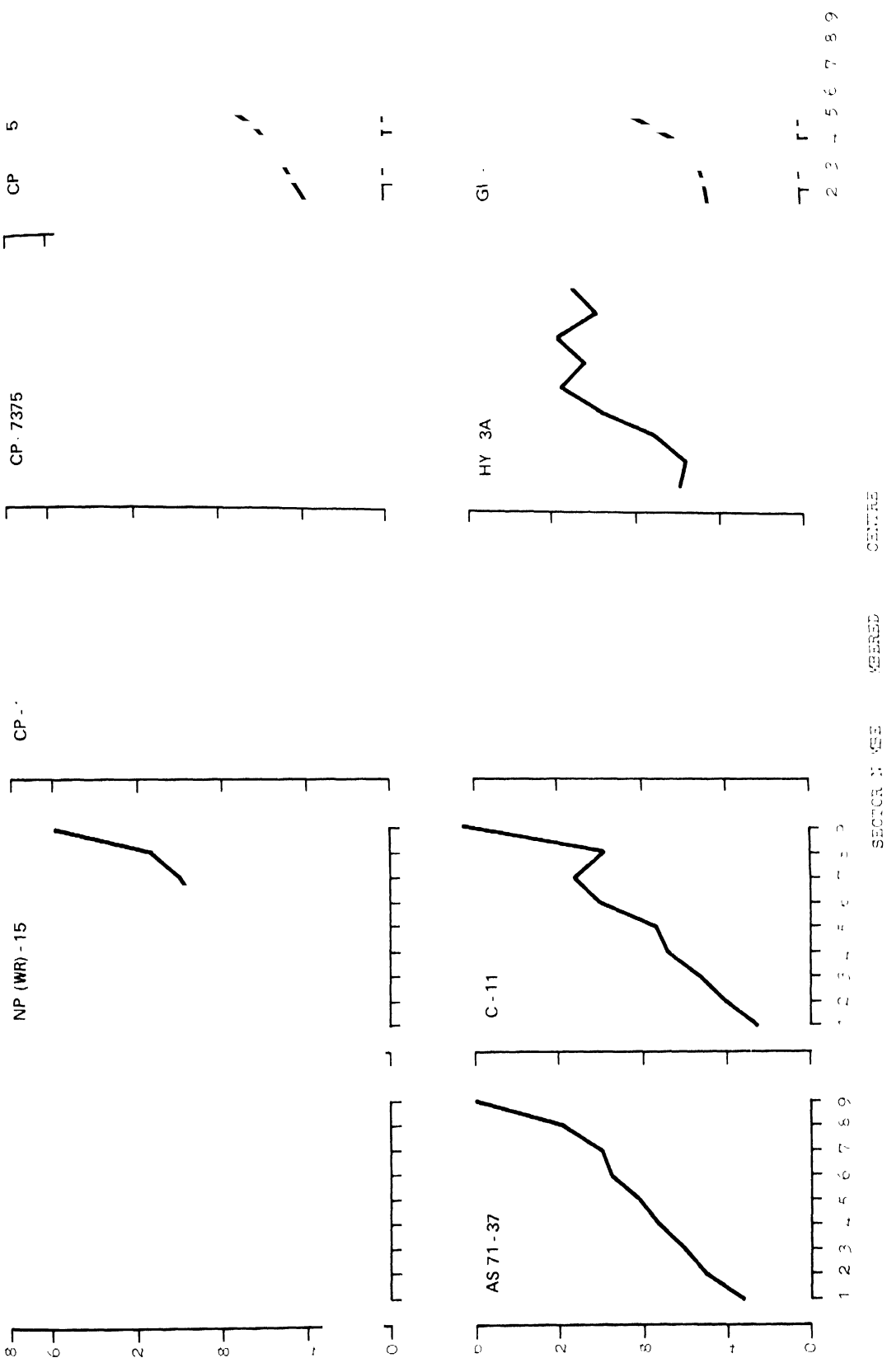
(d) Yield components:

As in the kharif season, there was little or no effect of row-spacing on seed number per pod or hundred seed weight (Fig.29). The differences in yield at different row spacings were accounted for by differences in pod number per plant.

As is generally the case, the 100 seed weights of cultivars grown in the rabi season were lower than those of the same cultivars grown in the kharif (compare Figs. 29 & 25).

FIGURE 26. EFFECT OF ROW SPACING ON BRANCHES TO MAIN STEM DRY WT. RATIOS AND HARVEST INDICES OF PIGEONPEA CULTIVARS GROWN IN RABI 1976-77





IGURE 27. EFFECT OF ROW SPACING ON GRAIN YIELD PER PLANT OF PIGEONPEA CULTIVARS GROWN IN BLACK SOIL (RABI 1978-7)

GUI 28. EFFECT OF ROI SPACI G ON GRAIN YIELD PE REA OF PIGI PEA CUI VARS GROWI ACI SOI RABI 1976

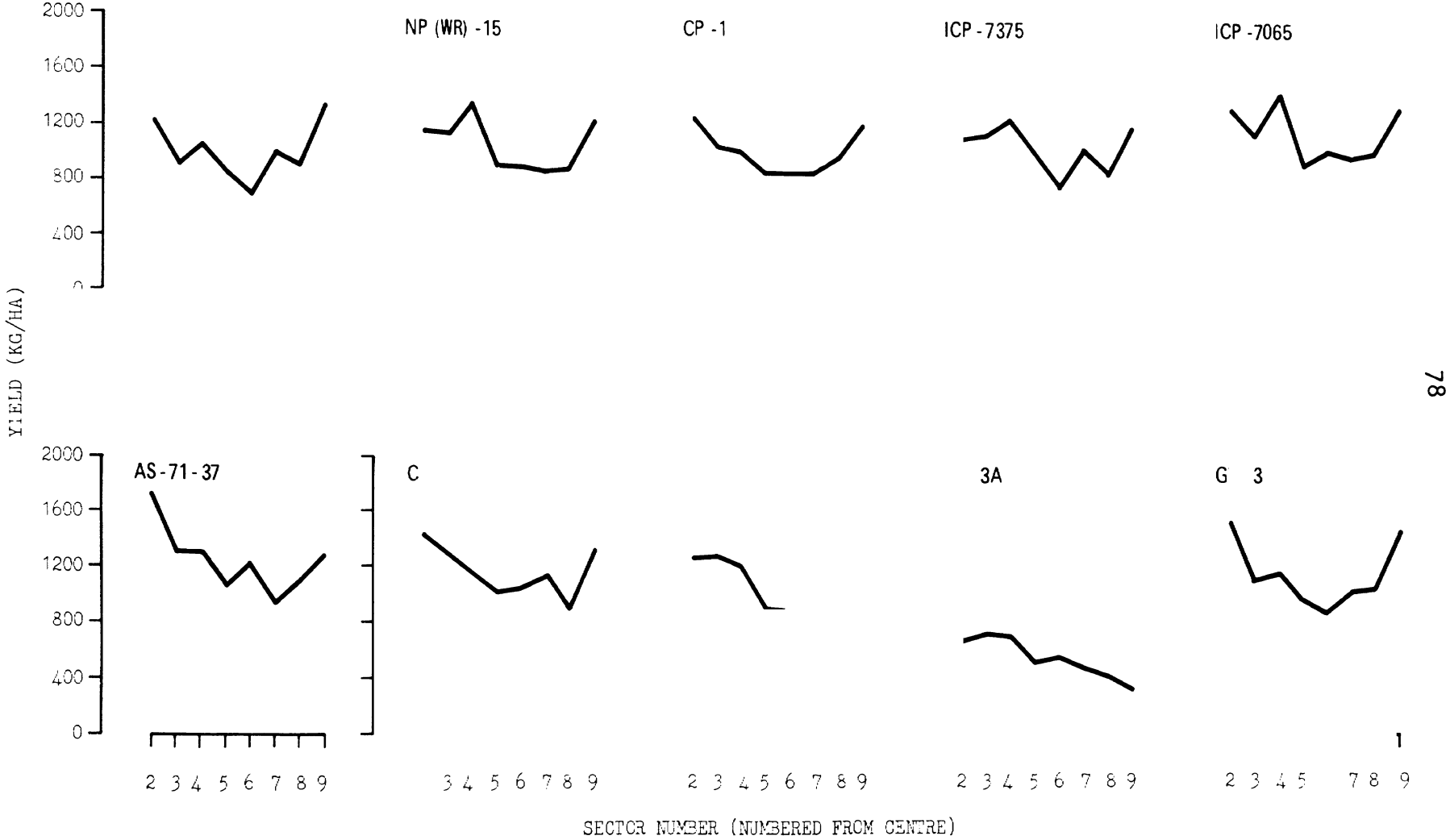
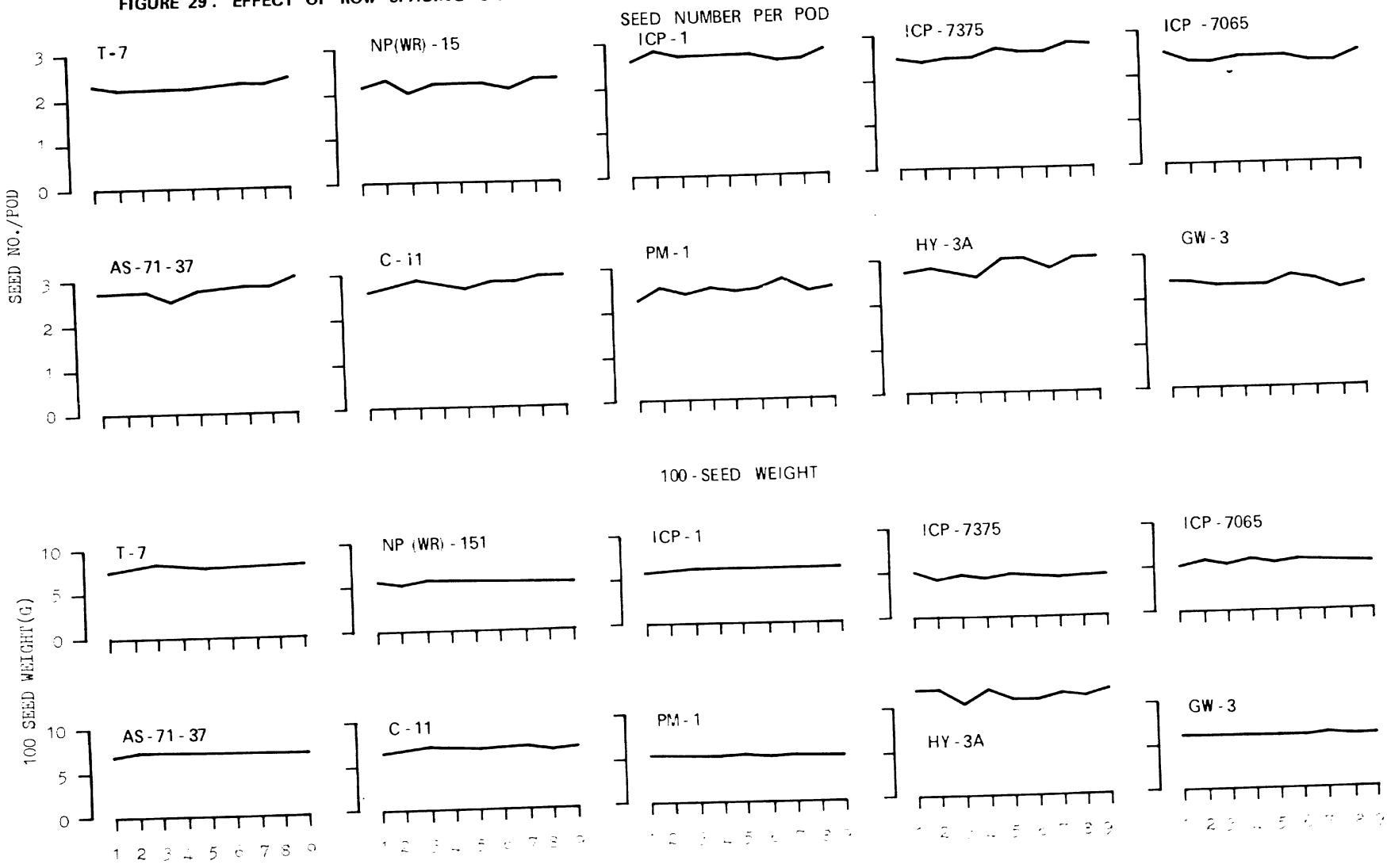


FIGURE 29. EFFECT OF ROW SPACING ON YIELD COMPONENTS OF PIGEONPEA CULTIVARS GROWN ON BLACK SOIL (RABI 1976-77)



Discussion

The constancy of seed number per pod and hundred seed weight over a wide range of spacings indicates that these characters can be selected for reliably at any spacing except in the case of large-seeded cultivars containing a higher number of seeds per pod, such as cv.HY-3A. However even in this case, although the 100-seed weight declined in the closer spacings on black soil (Fig. 25) it still remained higher than those of the other cultivars.

On the other hand in the kharif season the harvest index is affected by spacing to different extents in different cultivars, so measurements of HI under a given set of conditions may not give a reliable indication of HI under other conditions. HI also changes from season to season (compare Fig. 23 & 26). Furthermore, last year we found that it was higher in intercropped than in sole-cropped pigeonpeas (see PPR 1975/6 Section I.4).

In both the kharif and rabi seasons, cultivars which branched most at the wide row spacings also tended to branch most at the closer spacings; this was particularly striking in the case of cv. ICP-7375. Conversely cv. HY-3A at all spacings branched least.

The plant population in Sector 2 of the kharif-planted fans was approximately equivalent to the population normally used in yield trials of medium-duration pigeonpeas (75 x 30 cm spacings). On the red soil this spacing was close to the optimum for yield per unit area (Fig. 22); on black soil most cultivars showed a remarkable plasticity in response to spacing and yielded approximately the same over the range of populations from 7.3 to 1.1 plants/m^2 represented by sectors 1-9 of the fans (Fig.21). The greater plasticity exhibited on the black soil was probably because more water was stored in the soil enabling more growth to take place during the post-monsoon period. On the other hand the higher yields at the close spacings in the red soil than on the black may be a consequence of better growth of the plants on the red soil than on the black during the monsoon season itself, probably because of the better drainage and aeration of the soil.

The striking cultivaral differences in response to row spacing mean that selection for performance at wide row spacings cannot be carried out reliably at the 75 cm row spacing normally employed in yield trials. In inter-cropping systems employed by farmers, spacings of 3 m or more between pigeonpea rows are common. Our results indicate that a cultivar, such as HY-3A, which forms few branches and has an erect habit performs poorly at wide row-spacings and is therefore unlikely to do as well in an inter-cropping situation as the more branching, spreading cultivars. However, we do not yet have any evidence that the performance of widely-spaced pigeonpeas grown as a sole crop is correlated with their performance when grown at wide spacings in an intercrop, although this seems likely.

III.2

CULTIVARAL DIFFERENCES IN THE EFFECTS OF DEFOLIATION AT DIFFERENT STAGES OF GROWTH

Last year we found that the incidence of the wilt disease was greatly increased by defoliation during the reproductive phase on both black and red soils (see PPR 1975/6 Section V). The occurrence of this wilting in fields which had not been inoculated with *Fusarium* suggested that the pathogen was widely distributed and that the susceptibility of the plants depended to a large extent on their physiological state.

In order to investigate this phenomenon in more detail we carried out a trial in which plants of 6 cultivars were defoliated at different stages of growth. An additional objective in this experiment was to investigate cultivaral differences in response to defoliation treatments: these could reveal cultivaral differences in the ability to recover from severe stresses at different stages of growth.

Methods

The cultivars used in this trial were BDN-1, ICP-1, HY-3C, ICP-6997, C-11 and No.148. The trial was laid out as a split plot design (3 replicates) with cultivars in the main plots and defoliation treatments in subplots. The subplot size was 10 x 6 m. The trial was sown in red soil (field R1) on 5-7-76. There were six defoliation treatments, as below:

1. Control (no defoliation)
2. Control (no defoliation)
3. Total defoliation during mid vegetative phase (carried out on 13-8-76)
4. Total defoliation at late vegetative stage (carried out from 24/29-9-76)
5. Total defoliation during early reproductive phase (carried out for cv. No.148 from 10/14-10-76, for cv. BDN-1 from 17/20-10-76; for cvs. ICP-1, C-11 and ICP-6997 from 23/27-10-76 and for cv. HY-3C from 13/15-11-76).
6. Total defoliation plus removal of all flowers and pods during early reproductive phase (dates of treatments as in (5) above).

Total dry matter in the shoot system, yield and yield components were recorded at the time of harvest.

Results and discussion

i. Diseases:

This trial was beset by a number of problems. Firstly there was considerable seedling mortality owing to *Sclerotium* attack. A high inoculum of the fungus was present in the soil on sorghum straw which had been ploughed in at the end of the previous season. Reseeding was carried out, but the stands were uneven.

Secondly the field was poorly drained and the drains from higher-lying fields were not well constructed. As a consequence when there were heavy storms in August part of the field was badly waterlogged and the water from the overflowing field drains swept away almost all the plants from a number of plots. As a result most of the plots in one of the replications (Rep.II) were badly damaged and the whole replication had to be abandoned. Thirdly in late August and early September there was a severe attack of a disease which caused rotting of the stems in dark-coloured patches, and resulted in the collapse and death of the plants. This was identified by the Pulse Pathology Section as *Phytophthora* blight. This disease killed many plants of cvs. HY-3C and ICP-6997, but cvs. No.148, ICP-1 and BDN-1 were relatively unaffected. The relative incidence of the disease is indicated by the percentages of dead plants (scored on 7-9-76) in the two replicates which were not damaged by water-logging (Table 32). After these counts were taken, the disease continued to develop and killed over half the plants of cvs HY-3A and 6997.

Interestingly in cv. HY-3C and to some extent in cv. ICP-6997 the plants which had been defoliated in mid-August suffered much less from the disease than the plants in the other sub-plots. For example the percentages of plants killed by 7.9.76 in the non-defoliated plots of cv. HY-3C was 18.9% whereas only 0.6% of the defoliated plants had died. By the time of harvest the percentage of plants which had died was 20.0% in the plots which had been defoliated in mid-August, but in the other plots 64.8% of the plants had died. This could be either because the reduced canopy-cover in the defoliated plants somehow physically affected the transmission of the disease; alternatively it is possible that the defoliated plants were less susceptible to infection because of their physiological state (eg. less starch reserves).

Plants which had died as a result of waterlogging, blight or for any other reason were removed from the plots at the time flowering began. The plants which died between this time and the time of harvest could be identified easily. The cause of death during this period was assumed to be pigeonpea wilt, and this was confirmed in randomly sampled plants by looking for the characteristic dark streaks in the wood at the base of the stem.

Table 32. Percentage of dead plants in plots of pigeonpea cultivars on 7-9-76. The figures shown are means from counts made on replicates I and III, each of which contained about 1300 plants.

Cultivar	Dead plants as percentage of total	
	Replication I	Replication III
No. 148	1.8	1.6
BDN-1	0.7	0.1
ICP-1	0.9	0.5
C-11	1.8	3.2
ICP-6997	13.8	4.0
HY-3C	23.5	5.1

In the plots of cvs. BDN-1 and C-11 no wilted plants were found. In the other cultivars the overall percentage of dead plants was highest in cv. No.148 and lowest in ICP-1 (Table 33).

The relatively low overall incidence of wilt in the experiment may have been because there was a low level of inoculum of the pathogen in the soil. No inoculation of the soil was carried out before this experiment and pigeonpeas had not been grown in this field the previous year. The low incidence of the disease makes interpretation of the results uncertain, but in general they indicate that cvs. BDN-1 and C-11 were not susceptible to wilt even after defoliation at any stage of growth, whereas the incidence of wilt in cvs. ICP-6997 and HY-3C did appear to be related the physiological state of the plants as influenced by defoliation treatments (Table 33). A similar tendency was present in cv. ICP-1. In cv. No.148 the incidence of the disease was relatively high in the controls as well as in plants defoliated from September onwards. But only in cvs. ICP-6997 and HY-3C were the differences between treatments sufficiently large to suggest any consistent effect: in ICP-6997 the highest percentage of wilt occurred in plants defoliated during late September; in cv. HY-3C in those defoliated when flowering began. In the latter cultivar the incidence of wilt was less when the plants were deflowered as well as defoliated at the beginning of the reproductive phase.

Table 33. Percentage of wilted plants at the time of harvest in plants defoliated at different stages of growth.

Defoliation treatment	CULTIVAR				Mean
	ICP-1	No.148	ICP-6997	HY-3C	
Control	0.7	5.1	0	0	1.4
In mid-August	0	0	0	0	0
In late September	2.0	5.7	12.0	0	4 9
At flowering	1.4	7.3	4.9	15.2	7.2
At flowering+flower removal	0.5	7.4	4.6	6.2	4.7
Overall percentage in all treatments	0.9	5.2	2.7	2.8	

These results with cv. HY-3C are in agreement with our observations last year (see PPR 1975/6 Section V) that defoliation during the reproductive phase led to an increased incidence of the wilt disease, probably as a consequent of the reduction in the supply of assimilates or starch reserves available in the roots. The defoliation + deflowering treatment would have reduced the demand from developing pods in the period following the defoliation and may therefore not have reduced the availability of assimilates in the roots as much, and so the development of the wilt pathogen may have been reduced compared with the defoliation treatment alone.

The September defoliation may have resulted in lower starch reserves at the time of flowering began a month later in cv. ICP-6997 and hence to a higher incidence of wilt when competition from the pods depleted the already low reserves of carbohydrate. The lack of effect of this treatment on cv. HY-3A may be because flowering in this cultivar began three weeks later than in cv. ICP-6997 and therefore the plants may have had longer to recover from the effects of the defoliation.

ii. Yield:

In this trial the mean yields of all cultivars were low, and especially in the cultivars which suffered most from waterlogging and *Phytophthora* blight (cvs. ICP-6997 and HY-3C) the yields per unit area were reduced because of the poor plant stands (Table 34). For this reason the yields shown in Table 34 for the treatment effects are expressed on per plant basis.

Both defoliation treatments during the vegetative phase reduced mean yield significantly compared with controls but did not differ significantly from each other. Within the individual cultivars either one or both of these defoliations had a significant yield-reducing effect in cvs. C-11, ICP-6997 and HY-3C. The effects in cvs. No.148, BDN-1 and ICP-1 were smaller and not significant at the 5% level.

Defoliation at the time of flowering had a marked and significant yield-reducing effect in all cultivars. Defoliation + flower removal at this stage tended to give higher yields than defoliation alone, but the difference between the treatments was not significant at the 5% level. The tendency for the higher yields might be explicable in terms of the greater ability of the defoliated plants to recover from the defoliation by producing more new leaves when pod-set was delayed by flower-removal. This was clearly visible in the field.

Unfortunately the high coefficient of variation in this trial and the high LSDs do not permit many clear-cut conclusions; but there does seem to be an indication that some cultivars (No.148,BDN-1,ICP-1)

Table 34. Effects of defoliation at different stages of growth on yield per plant of 6 pigeonpea cultivars. (Mean yields per hectare are indicated at the bottom of the Table).

YIELD PER PLANT (g)

TREATMENT	CULTIVAR						Mean
	No.148	BDN-1	ICP-1	C-11	ICP-6997	HY-3C	
Control I	26.7	29.4	33.2	28.4	31.4	26.7	29.2
Control II	27.4	30.3	33.3	40.2	32.5	33.9	32.9
Defoliation at 40 days	21.5	24.5	24.3	14.3	18.3	16.1	19.8
Defoliation at 83 days	19.0	21.6	30.1	24.4	25.4	12.4	22.1
Defoliation at flowering	14.4	11.8	15.6	16.8	11.5	6.1	12.7
Defoliation and flower-removal at flowering	15.3	21.2	14.3	14.5	22.6	6.9	15.8
Mean	20.7	23.1	25.1	23.1	23.6	17.0	
Mean yield in kg/ha	649	813	940	620	378	273	

LSD (5%):

For cultivar means	12.13 (NS)
For treatment means	4.57
For treatments in a cultivar	11.21
For comparison of means in different groups	14.06
CV%:	24.8
(For cultivar mean yields in kg/ha:	413.8)

were better able to recover from the stress of total defoliation than cvs. ICP-6997 and HY-3C. Perhaps the most remarkable finding is that the plants were able to recover from total defoliation so well: the mean percentage reduction in yield caused by the total defoliations during the vegetative phase were only 29-37% and by total defoliation at the beginning of the reproductive phase 50-60%.

There was no significant effect of the defoliation treatments on 100-seed weights, except in the case of cv. HY-3C defoliated at the time of flowering when there was a reduction to 11.3 g compared with 14.0 g in the control.

III.3

EARLY AND LATER-FORMED PODS WITHIN THE RACEMES OF DIFFERENT CULTIVARS

Both within individual racemes and on the branches of indeterminate cultivars flowering begins at the lower nodes. Thus both within the racemes and on the branches the later-formed pods will tend to be found at the more apical nodes.

The racemes at the more basal nodes of branches generally have more pods than these at the apical nodes (see PPR 1974/5 Figs.21 & 22). These more basal racemes bear both early-formed pods and, at their more apical nodes, later-formed pods. By contrast the racemes from the apical part of the branch tend to bear only later-formed pods. If there were a decline in pod weight in the later-formed pods, we should observe a tendency for weight per pod to decline at the more apical pods of the branches, and also at the more apical nodes within racemes.

On branches such a decline does not in general take place (see PPR 1974/5 Figs. 21 & 22; PPR 1975/6 Section III.3 and this report Section III.4). In previous years we did not analyse the components of yield within the racemes. Such an analysis was carried out this year with a range of cultivars.

Methods

Racemes were collected from the basal parts of the branches of a range of cultivars growing in the 'fan' plantings and the experimental plots on both red and black soils. Racemes were collected from each cultivar in each replicate plot; after discarding racemes which were damaged by insects or mechanical injury, at least 100 racemes were used. The pods from the first, second, third etc. nodes of the raceme were separated, counted and their oven dry weights were recorded. They were then threshed and the seed numbers and seed weights were recorded. From these data the pod number per node within the raceme, 100 pod weight, 100 seed weight and seed number per pod were calculated.

Results and discussion

The 100 pod weights found at different node-positions within the racemes of 11 cultivars grown on both black and red soils are shown in Table 35. The ratios of the 100 pod weights at the upper two nodes to the 100 pod weights at the lower two nodes are also shown.

Table 35. 100 pod weights (g) at different node positions within racemes from the lower parts of branches of different cultivars grown on black & red soils.

Cultivar	Days to flowering	Soil	NODE POSITION WITHIN RACEME							Ratio upper 2 nodes:lower 2 nodes
			1	2	3	4	5	6	7	
T-21	86	Black+	29.9	28.3	26.0	18.6	21.6			0.69
		Red+	30.7	28.1	27.1	26.7	27.1			0.91
Pusa ageti	89	Black+	30.7	31.1	30.2	27.9	27.8	36.2		1.03
		Red+	36.0	34.2	36.6	38.6	33.8	32.2		0.94
HY-2	105	Black*	53.0	52.5	53.1	53.2				1.01
		Red*	53.9	50.5	46.3	47.2				0.90
BDN-1	112	Black*	37.1	37.1	35.7	38.1	38.2			1.03
		Red*	38.4	38.7	38.8	38.4	35.6	38.6		0.96
AS-71-37	115	Black*	41.7	42.0	41.7	38.2	45.0			0.99
		Red*	44.5	42.5	43.0	41.8	45.6			1.00
ICP-6997	115	Black+	62.1	62.9	85.6	69.4	69.4	68.2		0.94
		Black*	57.7	59.9	60.2	63.3	73.9	70.3		1.23
		Red*	51.0	59.6	59.4	75.3				1.22
ICP-1	116	Black+	42.3	43.2	41.9	42.5	43.4	38.7		0.96
		Black*	38.9	39.7	40.2	44.1				1.07
		Red*	39.6	39.7	40.2	36.2	36.1			0.91
ICP-7065	147	Black*	28.7	29.1	29.3	30.4	29.6	32.9	26.7	1.03
		Red*	23.5	24.9	28.2	27.3	29.4	30.2	31.3	1.27
NP(WR)-15	155	Black*	34.7	34.4	34.8	35.0	35.8	33.9		1.01
		Red*	25.8	26.5	28.4	30.2	31.9	27.3	28.0	1.06
ICP-7375	160	Black*	26.0	26.8	26.1	27.8	26.7	26.9		1.02
		Red*	22.6	24.8	22.8	26.8	28.1	27.5	24.9	1.11

+ ● Plants from experimental plots

* ◆ Plants from spacing trial (fans)

In a few cases there was a tendency for the later-formed (more apical) pods to be heavier than the earlier-formed pods; these differences were not found consistently within the same cultivar, but varied from treatment to treatment. On the other hand, in some cases, most strikingly in the case of cv. T-21 on black soil, there was a decline in 100 pod weight at the more apical nodes. But in most cases the ratio of upper to lower pod weights was close to unity. The changes in the 100 seed weights and seed number per pod in the earlier and later-formed pods were similarly small. There was a tendency for 100 seed weight to decline and for seed number per pod to rise in the later-formed pods. However this tendency was very slight as can be seen from Fig.30 which depicts the overall mean 100 seed and 100 pod weights and seed numbers per pod for the first four nodes within the racemes.

In general this analysis of yield components within the racemes agrees with the pattern found within the branches: on an average the later-formed and earlier-formed pods were similar in weight, and although there were a few cases where there was a decline in the later-formed pods, these were at least as many cases where there was an increase. Furthermore these changes were generally small and were not found consistently within cultivars. Once again, this emphasizes the very different behaviour of pigeonpeas from that of chickpeas where the later-formed pods may weigh only one half, or in some cultivars even less than one third, as much as the early-formed pods (see CPR 1975/6 Table 61).

The percentage of nitrogen in the seeds from pods at upper and lower nodes within the racemes was very similar (Table 36).

FIG. 30: SEEDS PER POD, 100 SEED WEIGHT AND 100 POD WEIGHT OF PODS AT DIFFERENT NODES WITHIN RACEMES; MEAN VALUES FOR 10 cvs GROWN ON BOTH BLACK AND RED SOILS

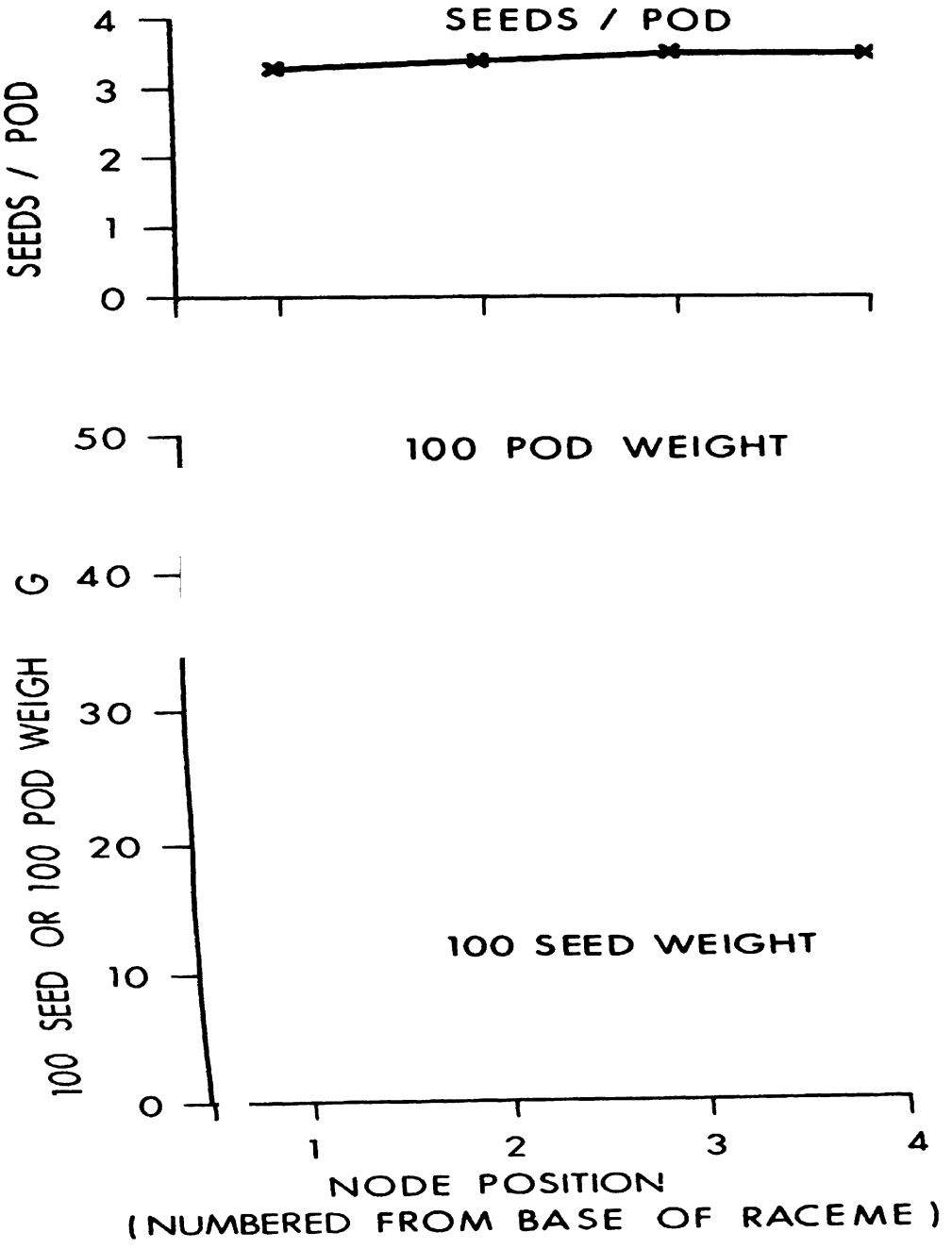


Table 36. Nitrogen percentage in the seeds taken from pods at the lower and upper nodes of the racemes of 9 pigeonpea cultivars grown on black soil.

Cultivar	NODES WITHIN THE RACEME	
	Lower	Upper
ICP-1	3.50	3.49
AS-71-37	3.37	3.48
BDN-1	3.60	3.44
ICP-6997	3.37	3.14
HY-2	3.61	3.40
HY-3A	3.29	3.24
ICP-7375	3.52	3.77
ICP-7065	3.60	3.20
NP(WR)-15	3.46	3.32
Mean	3.48	3.38

III.4

EARLIER-AND LATER-FORMED PODS WITHIN THE BRANCHES OF DIFFERENT CULTIVARS

On the branches of an indeterminate cultivar the racemes at the more basal nodes begin flowering and setting pods earlier than the racemes at the more apical nodes. In general, at the time of harvest the racemes from the basal nodes contain early-formed pods and also some later-formed pods, while those from the more apical nodes of the branches contain only later-formed pods. If the later formed pods contained fewer and/or smaller seeds than the early-formed pods, there should be a decline in average pod weight at the more apical nodes of the branches.

Last year pods were collected from the racemes at the upper and lower nodes of the branches of a range of cultivars. There was little or no effect of pod position within the branch on average pod weight (see PPR 1975/6 Table 31). There was also little effect of pod position within the racemes on average pod weights (see Section III.3 above). This year we made further observations on pods collected from the upper and lower parts of the branches of a range of cultivars.

Methods

Samples of at least 50 undamaged pods were collected from the upper and the lower parts of the branches at the time of harvest. From each genotype within each trial pods were collected from 3 or 4 replicate plots. After drying in the oven the pods and the seeds obtained from them were weighed and counted. From these observations 100 pod weight, 100 seed weight and seed number per pod were calculated. The data from each trial were analysed statistically, taking the cultivars as main plots and the upper and lower parts of the branches as 'sub-plots' of a split plot design.

Results

The results are summarized in Table 37. The ratios of the weights of pods from the upper and lower parts of the branches were in all cases fairly close to unity. Only in four cases were the differences in 100-pod weight significant at the 5% level: in two (cvs. HY-2(a) and IC-7035) the upper pods weighed less than the lower pods and in two (cvs. NP(WR)-15(c) and IC-7086) they weighed more. However cvs. HY-2 and NP(WR)-15 were sampled from more than one set of experimental plots and the other samples showed no significant difference between the upper and lower pods. We can conclude that in

Table 37. Characteristics of pods from upper and lower parts of branches of 22 pigeonpea cultivars. The samples were taken from plants in three separate trials (a) genotypic comparison trial in black soil (b) spacing trial ('fan') in black soil and (c) spacing trial ('fans') in red soil. The data were analysed separately for the three trials and SEs and LSDs are shown for each trial at the bottom of the table. Pairs of data which differ significantly from each other at the 5% level are indicated with asterisks.

Cultivar	Days to flowering	Trial	100 seed wt. (g)		Seeds/pod		100 pod wt. (g)		Ratio of pod weight
			Upper	Lower	Upper	Lower	Upper	Lower	Upper / Lower
Prabhat	69	a	6.3	7.0	3.26	3.20	27.8	32.6	0.85
UPAS-120	80	a	7.4	6.7	3.10	3.24	39.9	37.4	1.06
T-21	85	a	7.8	7.6	2.88	3.14	34.2	37.3	0.92
HY-1	100	a	8.7	8.2	2.89	3.08	37.0	36.9	1.00
HY-2	105	a	12.5	11.9	3.04	3.18	56.5	57.0	0.99
HY-2		b	11.6	12.1	3.46	3.50	54.2*	57.9*	0.94
HY-2		c	10.5	10.8	3.55	3.58	51.4	53.9	0.95
HY-4	105	a	8.6	8.8	2.77	3.01	38.3	39.3	0.97
BDN-1	112	a	9.9	8.9	2.93	2.64	39.6	33.9	1.17
BDN-1		b	9.0	9.0	3.28	3.22	38.8	38.7	1.00
BDN-1		c	9.3	9.5	3.21	3.11	40.7	40.1	1.01
C-11	125	a	9.5	10.2	2.87	3.10	39.5	44.1	0.90
6997	115	a	12.7	12.8	3.55	3.68	69.3	70.4	0.98
6997		b	12.6	13.2	3.79	3.83	67.9*	71.8*	0.95

Contd....Table 37

Cultivar	Days to flowering	Trial	100 seed wt. (g)		Seeds/pod		100 pod wt. (g)		Ratio of pod weight
			Upper	Lower	Upper	Lower	Upper	Lower	Upper/Lower
6997		c	17.2	16.9	4.11	4.07	77.2	78.1	0.99
AS-71-37	115	b	9.8	10.0	3.29	3.40	43.0	45.6	0.94
AS-71-37		c	9.8*	10.6*	3.46	3.22	44.6	45.1	0.99
ICP-1	116	b	9.9	9.7	3.07	3.12	42.5	41.8	1.02
ICP-1		c	9.1	9.3	3.28	3.21	41.7	43.5	0.96
6914	119	a	10.4*	12.9*	4.10	3.68	79.0	83.1	0.95
HY-5	-	a	9.8	10.4	3.06	2.68	44.5	44.8	0.99
C-11	125	a	9.5	10.2	2.87	3.10	39.5	44.1	0.90
7035	136	a	18.6	19.4	3.43	3.60	96.1*	105.3*	0.91
HY-3C	140	a	15.3	16.4	3.94	4.02	95.6	99.4	0.96
HY-3A	140	a	14.8	15.9	3.62	3.98	81.8	85.4	0.96
HY-3A		b	17.6	17.3	3.87	3.96	102.9	100.8	1.02
7065	147	a	6.4	6.1	2.77	3.01	29.3	27.6	1.06
7065		b	6.9	7.2	2.90	3.08	32.0	33.4	0.96
7065		c	6.3	6.6	3.10	3.00	30.2	31.5	0.96
NP(WR)-15	155	a	7.0	7.0	2.96	2.79	32.2	29.8	1.08
		b	7.9	7.8	3.04	3.00	36.2	34.5	1.05
		c	7.9	7.6	2.99	2.90	46.3*	37.2*	1.24
7375	160	a	5.4	5.0	3.31	2.90	27.8	22.6	1.23
		b	6.2	6.3	3.30	3.18	29.4	28.7	1.02
		c	5.8	5.5	3.46	3.45	30.6	28.5	1.07

Contd...Table 37.

Cultivar	Days to flowering	Trial	100 seed wt. (g)		Seeds/pod		100 pod wt. (g)		Ratio of pod weight
			Upper	Lower	Upper	Lower	Upper	Lower	Upper/Lower
6986	161	a	9.5	10.2	4.26	3.95	62.2	61.8	0.96
7086	162	a	13.8*	11.5*	2.91	3.01	64.9*	53.5*	1.21
NP-69	176	a	12.6	12.1	3.20	3.19	62.7	59.8	1.05
Overall Mean			10.1	10.2	3.30	3.29	50.5	50.6	1.01

LSD (5%) (for comparison of means of pod position within cultivars)

a	1.73	0.572(NS)	8.32
b	0.61(NS)	0.202(NS)	3.45
c	0.76	0.463(NS)	4.51

SE±

a	0.87	0.286	4.16
b	0.29	0.098	1.68
c	0.35	0.212	2.07

CV%

a	11.7	12.5	11.1
b	4.1	4.4	4.8
c	5.2	8.1	6.6

agreement with results from past years, there was in general no difference in the weight of earlier and later-formed pods; from this year's results the only possible exception might be cv. 7035, but even in this case the decline in the later-formed pods was small (9%).

There were no significant differences in seed number per pod in the pods from the upper and lower pods of the branches. In two cases (cv. AS-71-37c and IC-6914) the 100 seed weights significantly declined in the upper pods and in one case (cv. IC-7086) increased. However only in the latter case was this change associated with a significant change in 100 pod weight.

The nitrogen percentage in the seeds from the upper and lower parts of the branches were very similar (Table 38).

In the above comparisons LSD's at the 5% level were used, which means that in one case out of 20 the comparison of the 100 mean pod weights and 100 seed weights from the upper and lower parts of the branches could differ by chance alone. In all, 37 sets of such comparisons are shown in Table 37. Therefore about 2 sets of differences could appear significantly different at the 5% level by chance; the fact that only 3 and 4 pairs appeared different in the comparisons of 100 seed weights and 100 pod weights respectively further emphasizes the similarity of the early and later-formed pods in the genotypes studied as far.

Discussion

This method of comparing early and later-formed pods is simple to carry out and seems to give repeatable results. It could probably be used successfully on a large scale to screen hundreds of genotypes in an attempt to identify lines in which pod-set is not limiting yield. In such lines the later-formed pods would be expected to weigh less than the earlier-formed pods because if pod-set were not limiting yield, the supply of assimilates or nutrients to the pods would be limiting pod-filling. Of course such a screening procedure would be preliminary and rather crude, but it could enable a number of genotypes to be identified for more intensive investigation.

Table 38. Nitrogen percentage in the seeds taken from pods from the lower and upper parts of the branches of 9 pigeonpea cultivars grown on black and red soils.

Cultivar	BLACK SOIL		RED SOIL	
	Lower	Upper	Lower	Upper
ICP-1	3.50	3.46	3.31	3.14
AS-71-37	3.30	3.50	3.31	3.36
BDN-1	3.64	3.65	3.28	3.33
ICP-6997	3.31	3.14	-	-
HY-2	3.33	3.53	3.10	3.14
HY-3A	3.22	3.15	3.50	3.42
ICP-7375	3.59	3.65	3.52	3.65
ICP-7065	3.83	3.49	3.39	3.65
NP(WR)-15	3.61	3.78	3.53	3.60
MEAN	3.48	3.48	3.37	3.41

III.5.

CULTIVARAL DIFFERENCES IN SPECIFIC LEAF WEIGHT AND IN THE REMOBILIZATION OF NITROGEN DURING LEAF SENESCENCE

Studies of a range of cultivars by the Pigeonpea Breeding Section have shown that there are highly significant cultivaral differences in specific leaf weight (see ICRISAT Pigeonpea Breeding Report 1974/5 pp 128-130 and 1975/6 pp 51-57). Last year we found that there were also cultivaral differences in the extent to which the specific leaf weights and the nitrogen content of the leaves declined during the process of leaf senescence (see PPR 1975/6 Section I.5). This year we investigated these changes in nine cultivars grown on black and red soils.

Methods

Green, yellow and fallen leaf-laminae and their petioles were collected in five replicates from plants grown in the spacing trial (described in Section III.1). The leaf area of the green and yellow leaf-laminae and their oven dry weight were recorded. Laminae and petioles from three replications were pooled and ground to powder for nitrogen analysis by the Kjeldahl method. The data on specific leaf weight were analysed statistically as a split plot design with leaf age in 'main plots' and cultivars in 'sub-plots'.

Results and Discussion

The specific leaf weight of the green and yellow leaves on both black and red soils are shown in Table 39. On both soils the mean decline in SLW was significant and on both soils there were significant differences between cultivars in the SLW of green leaves and of yellow leaves. The decreases in SLW varied from cultivar to cultivar(Table 40). However for none of these variables was there any significant correlation between the results from the red and black soils (Table 41).

The nitrogen percentage in the laminae and petioles of green, yellow and fallen leaves are shown in Tables 42 and 43. There were cultivaral differences in all variables including the decline in nitrogen percentage from green to fallen leaf-laminae and petioles. However there was again no significant correlation between the results from black and red soils (Table 41) except in the nitrogen percentage in fallen leaves where there was a significant negative relationship.

The contribution of nitrogen remobilized to the developing pods from the leaves is very considerable (see Section I.1.D); cultivaral

Table 39. Specific leaf weights of green and yellow leaves of 9 pigeonpea cultivars grown on black and red soils.

Specific leaf weight (mg/cm^2)

Cultivar	BLACK SOIL			RED SOIL		
	Green	Yellow	Mean	Green	Yellow	Mean
AS-71-37	5.05	3.67	4.36	4.84	4.25	4.55
BDN-1	4.87	4.87	4.87	5.15	4.51	4.83
HY-2	4.49	4.29	4.39	5.56	4.41	4.99
ICP-1	5.08	3.35	4.22	5.38	4.34	4.86
ICP-6997	5.10	4.25	4.68	5.11	4.79	4.95
HY-3A	6.74	3.74	5.24	5.87	5.14	5.51
ICP-7065	4.73	3.59	4.16	4.93	3.70	4.32
ICP-7375	5.32	4.41	4.87	3.81	5.71	4.76
NP(WR)-15	4.51	4.29	4.40	5.44	4.24	4.84
MEAN	5.10	4.05		5.12	4.57	

LSD (5%):	Black soil	Red soil
For leaf age	0.276	0.158
For cultivar	0.242	0.296
For leaf age within a cultivar	0.342	0.420
For cultivars within a leaf age	0.683	0.411
CV% leaf age	10.3	5.6
CV% cultivars	11.8	6.8

Table 40. Decrease in specific leaf weights from green to yellow leaves in 9 pigeonpea cultivars grown on black and red soils.

Cultivar	DECREASE IN SLW (mg/cm^2)	
	Black soil	Red soil
AS-71-37	1.38	0.59
BDN-1	0.00	0.64
HY-2	0.20	1.15
ICP-1	1.73	1.04
ICP-6997	0.85	0.32
HY-3A	3.00	0.73
ICP-7065	1.14	1.23
ICP-7375	0.91	-1.90
NP(WR)-15	0.22	1.20

Table 41. Correlation coefficients between specific leaf weights and nitrogen percentages in leaves and petioles of 9 pigeonpea cultivars grown on black and red soils.

Variable	Correlation between value on black and red soils
SLW of green leaves	0.18
SLW of yellow leaves	0.34
Decline in SLW from green to yellow leaves	0.01
N% in green leaves	0.08
N% in fallen leaves	-0.64*
Decrease in N% from green to fallen leaves	0.23
N% in petioles of green leaves	0.45
N% in petioles of yellow leaves	0.07
Decrease in N% of petioles from green to fallen leaves	0.50

* Significant at 5% level (8 d.f.).

Table 42. Nitrogen percentage in laminae of green, yellow and fallen leaves of pigeonpea cultivars grown on black and red soils.

Cultivar	NITROGEN PERCENTAGE IN LEAF LAMINAE							
	LEAVES FROM PLANTS ON BLACK SOIL				LEAVES FROM PLANTS ON RED SOIL			
	Green	Yellow	Fallen	Decrease from green to fallen	Green	Yellow	Fallen	Decrease from green to fallen
AS-71-37	4.20	1.65	1.33	2.87	4.24	2.45	1.89	2.35
BDN-1	3.99	1.60	1.35	2.64	4.04	2.04	1.51	2.53
HY-2	4.27	1.87	1.08	3.19	4.00	1.96	1.80	2.20
ICP-1	4.90	2.15	1.45	3.45	3.71	1.79	1.31	2.40
ICP-6997	3.52	1.69	1.36	2.16	3.86	1.53	1.67	2.19
HY-3A	4.42	2.09	1.49	2.93	4.19	2.23	1.56	2.63
ICP-7065	4.19	2.10	1.42	2.77	3.83	2.15	1.51	2.32
ICP-7375	4.19	1.63	1.44	2.75	3.76	2.02	1.54	2.22
NP(WR)-15	4.32	1.64	1.36	2.96	4.16	2.03	1.69	2.47
MEAN	4.22	1.82	1.36	2.86	3.98	2.02	1.61	2.37

Table 43. Nitrogen percentage in petioles of green, yellow and fallen leaves of pigeonpea cultivars grown on red and black soils.

NITROGEN PERCENTAGE IN PETIOLES

Cultivar	PETIOLES FROM PLANTS ON BLACK SOIL				PETIOLES FROM PLANTS ON RED SOIL			
	Green	Yellow	Fallen	Decrease from green to fallen	Green	Yellow	Fallen	Decrease from green to fallen
AS-71-37	1.26	1.03	1.00	0.26	1.14	1.14	0.82	0.32
BDN-1	1.51	0.90	0.67	0.84	1.26	1.19	0.71	0.55
HY-2	1.74	1.35	0.83	0.91	1.38	1.33	0.88	0.50
ICP-1	1.60	1.40	0.87	0.73	1.20	0.97	0.61	0.59
ICP-6997	1.11	1.02	0.68	0.43	1.24	0.92	0.69	0.55
HY-3A	1.30	1.12	0.80	0.50	1.14	1.23	0.88	0.26
ICP-7065	1.38	1.07	0.60	0.78	1.26	1.52	0.91	0.35
ICP-7375	1.21	1.01	0.78	0.43	1.30	1.15	1.05	0.25
NP(WR)-15	1.38	0.95	0.74	0.64	1.23	1.15	0.92	0.31
MEAN	1.39	1.09	0.77	0.61	1.24	1.18	0.83	0.41

differences in the extent of this remobilization could be important. However the results in Tables 39 to 43 show that although cultivaral differences exist, there is a strong interaction between cultivars and the environments. This indicates that the cultivaral differences in these leaf variables are showing a low heritability; hence the collection of further data on these variables will probably not be of much use to the breeders.

III.6

CULTIVARAL DIFFERENCES IN THE SALT-AND ALKALI-TOLERANCE OF GERMINATING SEEDS AND SEEDLINGS

Some of the soils in pigeonpea-growing areas are affected by salinity and/or alkalinity. Under such conditions pigeonpea cultivars whose germination, growth and yield are affected to the minimum extent would be of advantage.

We carried out some preliminary work on the ability of different cultivars to germinate under saline and alkaline conditions both in the laboratory and in the field.

Materials and Methods

1. Germination in Petri dishes:

Petri dishes were lined with filter paper. 25 ml of test solution were added. Twenty seeds were placed in each dish with four replicate dishes per cultivar. The petri dishes were kept at lab temperature (around 30°C) and were scored for radicle emergence after 24 hours, for plumule emergence after 48 hours, and for the number of living seedlings after 6 days. The test solution for the salinity trials contained a 1:1 mixture of NaCl and $CaCl_2$ at a concentration of 1.5%. In testing for alkali tolerance a 0.5% solution of sodium bicarbonate was used. Distilled water was used for the controls.

2. Germination in the field:

Eighteen lines were sown in three replicates in alkaline saline soil in field B-10, on 8-7-76. Thirty-three seeds of each cultivar were sown in each replicate.

The soil samples taken from the area in which this trial was sown showed a range of PH from 8.25-9.30 (mean: 8.8) and electrical conductivities in a 1:2 extract ranging from 0.3-1.5 mmhos/cm (mean: 0.8).

The plots were scored for seedling emergence on 6-8-75.

Results and Discussion

1. Germination in Petri dishes:

Seeds from a range of 15 cultivars differing in seed size, duration and plant type were compared with respect to their ability to

germinate in saline and in alkaline solutions. The data for radical emergence at 1 day, plumule emergence at 2 days and living seedlings at 6 days are shown in Table 44. In both saline and alkaline solutions in most cultivars the number of seedlings which survived until 6 days was considerably less than the number which developed radicals and plumules after one and two days. The coefficient of variation also rose to over 70% for living seedlings scored after six days. In both saline and alkaline solutions an analysis of variance showed that the cultivaral differences in the percentage of seedlings surviving at 6 days were significant at the 1% level.

The two cultivars which fared best in the alkaline solution, HY-3C and HY-3A, were the largest-seeded; the cultivars which performed more poorly were generally smaller-seeded. This suggests the possibility that seed size may have influenced the survival of the seedlings at this early stage and may have masked differences in alkali-tolerance which might have shown up in older seedlings.

In the saline solution, there was a significant relationship between radical emergence at 24 hours and living seedlings at 6 days ($r = 0.43^{**}$) but this was not close enough to use radical emergence as a satisfactory criterion; plumule emergence scored at two days was not significantly related to living seedlings scored at 6 days ($r = 0.07$). In alkaline solutions the correlations were better (Table 45) but not good enough to use radical or plumule emergence as reliable indices of seedling survival.

There was no significant correlation between the survival of seedlings in saline and in alkaline solutions ($r = -0.04$).

Seeds of a further 59 cultivars were tested for their ability to germinate in alkaline solutions. Again a wide range was found ~~that~~ with statistically significant differences (Table 46).

We regard these results as merely preliminary; cultivars which showed widely different tolerances in these tests will be investigated further and in more detail.

2. Germination in the field:

The alkalinity and salinity in the field was patchy and ununiform, and so was the germination of the seedlings. The analysis of variance showed significant differences (at the 1% level) between replications and also between cultivars. The results are shown in Table 47. It can be seen that cv. HY-3C was one of the poorest cultivars whereas when screened for alkali tolerance in Petri dishes

Table 44. Number of seeds as percentage of controls from which radicals plumules and living seedlings developed in saline or alkaline solutions.

Cultivar	PERCENTAGE OF CONTROL							
	IN SALINE SOLUTIONS			IN ALKALINE SOLUTION			RANKING FOR LIVING SEED	
	Living seed-lings	Plumule emer-gence	Radical emer-gence	Living seed-lings	Plumule emer-gence	Radical emer-gence	In saline solution	In alkaline solution
T-21	59	59	84	3	5	28	1	13
HY-1	46	73	81	10	19	71	2	6
HY-5	28	82	71	27	44	86	3	3
HY-2	11	74	43	25	27	80	4	4
NP(WR)-15	10	89	85	4	10	63	5	11
HY-3C	9	85	31	41	46	65	6	1
HY-3A	4	26	9	31	39	60	7	2
BDN-1	4	74	53	2	3	17	8	14
ICP-1	4	64	75	4	5	26	8	10
ICP-7065	3	76	72	1	8	38	8	15
No.148	2	69	65	3	5	36	11	12
ICP-6997	1	75	27	7	10	57	12	7
HY-4	1	47	49	7	5	34	13	7
AS-71-37	0	81	60	5	6	27	14	9
Pusa Ageti	0	63	55	14	3	46	14	5
LSD (5%)	12.2	22.9	21.2	13.7	13.5	24.5		
CV(%)	70.9	23.2	25.8	78.1	60.9	35.0		

it was the best. This may have been because of alkali-salinity interactions; it may also reflect the unreliability of the methods. We have little confidence in these results. We hope to develop better-defined conditions for comparing the germination and growth of different cultivars in artificially salinized and alkalinized soils.

Table 45. Correlation matrix for living seedlings, plumule and radical emergence of 15 cvs. tested for salt and alkali tolerance (59 d.f.).

Living seedlings in salt	1					
Plumule emergence in salt	0.07	1				
Radical emergence in salt	0.43**	0.44**	1			
Living seedlings in alkali	-0.04	-0.16	-0.40**	1		
Plumule emergence in alkali	0.09	-0.05	-0.34**	0.86**	1	
Radical emergence in alkali	0.15	0.11	-0.13	0.59**	0.68**	1

** Significant at the 1% level.

Table 46. Number of living seedlings as percentage of controls after germination in 0.5% $NaHCO_3$ solution for 6 days.

Cultivar or ICP-number	% living seedlings	Cultivar or ICP-number	% living seedlings
Daincha	74	*C* x *A. scarabaeoides*	6
3868 (W)	63	NP(WR)-15-116-1	6
3868 (B)	39	P-334	6
C x *A. lineata* 1791	34	P-1195-54-2	5
C x *A. sericea* 2000	29	5431	5
C x *A. lineata* 1776	29	1022	4
C x *A. sericea* 2051	28	EC-109917	4
C x *A. sericea* 2023	28	*C* x *A. sericea* 1984	4
NP-69	26	P-934-4-4	4
C x *A. scarabaeoides* 1917	26	P-173-12-1	3
3D-8104	24	*C* x *A. scarabaeoides* 1919	3
JA-278-1	23	3462	3
P-448-2-3	22	PD-3	3
JA-275	18	7599	2
4353	17	GW-3-191-1	2
6394	17	Co.19	2
P-300-20-1	15	*C* x *A. lineata* 1787	2
P-4750-49-1	15	7115	0
24-P-2778-B-2	14	6917	0
C x *A. sericea* 1992	13	6854	0
C-11	12	*C* x *A. lineata* 1781	0
C x *A. scarabaeoides* 1916	12	7375	0
P-191-118-1	12	*A. platycarpa*	0
C x *A. scarabaeoides* 1914	12	P-240-129-2	0
ST-1	10	1405	0
Mukta	10	769	0
4255	8	*C* x *A. lineata* 1794	0
4609	8	7332	0
5331	7	P-240-129-3	0

Coefficient of variation : 37%

LSD (5%) = 2.6

Table 47. Living seedlings as a percentage of seeds sown in alkaline-saline soil (field B-10) scored one month after sowing.

Cultivar	Seedlings as % of seeds sown
ST-1 x Baigani	23
No.148 x Baigani	19
C-11	18
ST-1 x No.148	17
No.148	15
ST-1	14
ST-1 x HY-3C	14
C-11 x No.148	13
P-9-140-3	13
C-11 x Baigani	13
NP(WR)-15	12
C-11 x ST-1	10
Baigani	8
No.148 x HY-3C	6
HY-3C	2
S-10-190-1	2
EC-107634	2
JA-275	2

CV : 38%
LSD (5%): 7.2

III.7

OVULE NUMBERS IN EARLIER AND LATER-FORMED FLOWERS

Last year we carried out a preliminary investigation on varietal differences in the realization of the yield potential of pods (see PPR 1975/6 Section III.2). The method depended on comparing the numbers of seeds produced per pod with the number of ovules per carpel in the flowers. The latter number sets an upper limit on the potential seed number per pod. Such comparisons depend on being able to estimate the ovule number per carpel accurately. This can be done by collecting and dissecting hundreds of flowers. If the ovule number per carpel changed during the flowering period, samples of flowers would have to be collected on more than one occasion.

We therefore carried out a small investigation to find out whether or not the ovule number per carpel was the same in earlier-and later-formed flowers. Such flowers were collected from three late cultivars near the beginning (1-12-76) and towards the end (24-12-76) of the flowering period. The flowers were preserved in formalin-propionic acid-alcohol fixative until they were dissected for ovule-counting. The results are shown in Table 48. There was no significant difference between the ovule numbers in the earlier and the later-formed flowers. This indicates that flower samples need be taken only at one time during the flowering period in order to estimate the maximum potential seed number per pod.

Table 48. Ovule numbers per carpel in earlier and later-formed flowers of pigeonpeas. The ovule numbers shown represent the means (with standard deviations) from 6 replicate samples of at least 25 flowers each.

Cultivar	Ovule number per Carpel	
	Earlier-formed flowers	Later-formed flowers
ICP-7375	3.74 ± 0.022	3.65 ± 0.147
ICP-7065	3.30 ± 0.169	3.43 ± 0.108
NP(WR)-15	3.67 ± 0.070	3.63 ± 0.126

III.8

HEREDITARY DIFFERENCES IN SEED SIZE WITHIN A CULTIVAR

Last year we found that there was a considerable variation in the average 100-seed weights produced by individual plants of a given cultivar (see PPR 1975/6 Section IV.2 Fig.37). When plants were grown from seed which had been graded into large and small sizes, there was no effect on the yield, but the plants grown from large seeds gave seeds with 100-seed weights significantly higher than those from plants grown from small seeds (see PPR 1975/6 Table 34). Plants grown from ungraded seeds gave seeds of intermediate 100-seed weights. These results indicated that part of the variation of seed size within a cultivar was hereditary. In order to investigate this further, we took seeds from individual plants which produced seeds of different average 100-seed weights. These seeds were sown in the kharif of 1976 and the resulting plants were harvested in four replicates. The average 100-seed weights are shown in Table 49. It can be seen that the average 100-seed weights of the progeny were related to the average 100-seed weights of the parents. This confirms last year's observations that heritable differences for 100-seed weight exist within pigeonpea cultivars, and emphasizes that these cultivars are far from being pure lines, but are genetically heterogenous.

Table 49. Effects of parental seed size on mean seed size produced by progeny.

Cultivar	100-seed weight (g)	
	Mean seed size of parent plant	Mean seed size of progeny
ST-	6.3	6.99 ± 0.37
ST-	6.7	7.10 ± 0.80
ST-	7.1	7.08 ± 0.34
ST-	7.4	7.19 ± 0.18
ST-	8.0	8.09 ± 0.49
ST-1	Small	7.84 ± 0.40
ST-1	Large	8.43 ± 0.99
ICP-1	Small	8.03 ± 0.33
ICP-1	Large	9.68 ± 0.97
HY-3C	Small	9.56 ± 1.35
HY-3C	Small	10.11 ± 3.01
HY-3C	Large	13.68 ± 1.71

IV.1

AFTER-EFFECTS OF PIGEONPEA ON SUBSEQUENT CROPS

Last year we observed that when pigeonpeas were grown in places where there had been a pigeonpea crop in the previous season, the growth of the plants was severely stunted and the grain yield was much reduced (see PPR 1975/6, Section IV.1). Two alternative explanations seemed possible: that this effect was caused by parasitic nematodes or that it was allelopathic, i.e. the result of toxic chemicals released into the soil by the previous year's pigeonpea crop or its decaying residues.

This year we investigated the residual effect of pigeonpeas on a variety of subsequent crops in black and red soils. We also carried out two different types of experiments in the field to investigate whether pigeonpea crop residues (roots and leaves) were having an allelopathic (toxic) effect. In one of these experiments we investigated the effects on a pigeonpea crop of incorporating pigeonpea leaves or both roots and leaves into soil in which pigeonpeas had not previously been grown. The other type of experiment involved removing the roots and/or leaves of pigeonpeas from the soil in which a previous pigeonpea crop had been grown.

Methods

(i) In both red (RA-26) and black (ST-1) soils a number of crops were planted in 4 x 7.5 m plots in areas where a pigeonpea crop had been grown the previous year and in adjacent areas when pigeonpea had not been grown. In each four replicate plots of each crop were planted in a randomized block design within treatments. The cultivars or hybrids of the crops were as follows:

Red soil	Black soil
Pigeonpea (ST-1)	Pigeonpea (T-21)
Groundnut (TMV-2)	Groundnut (TMV-2)
Cowpea (New Era)	Cowpea (New Era)
Sorghum (CSH-5)	Sorghum (CSH-5)
Pearl Millet (HB-3)	Pearl Millet (HB-3)
Castor (157-B)	Chickpea (JG-62) (in rabi).

In all plots the plants were sown by hand on ridges 75 cm apart with the following plant-to-plant spacings: cowpea, pearl millet and chickpea, 10 cm; groundnut and sorghum, 15 cm; cotton, castor and pigeonpea 30 cm. Dates of sowing were: red soil-25-6-76, black soil-38-6-76. The chickpea was sown in late October 1976 and given post-sowing irrigation to ensure germination.

Sorghum, pearl millet, cotton and castor received nitrogenous fertilizer (CAN) at the rate of 40 Kg N/ha as basal dose and a subsequent topdressing of 40 Kg N/ha. All crops were protected by regular sprays of insecticides.

Total dry weight of the shoot system and yield were recorded at the time of harvest. The means of the four replicates of each crop within each treatment were calculated with standard deviations.

(ii) In areas of fields ST-1 (black soil) and RA-26 (red soil) where pigeonpea had not previously been grown, pigeonpea residues (leaves and roots) which had been collected from previous year's pigeonpea plots were incorporated into the soil as follows: control (no incorporation). leaf incorporation and leaf+root incorporation. The leaves and roots were added in the same quantities as those produced by the previous pigeonpea crop growing in plots of the same size. Plot size were 6 x 5.25 m. The treatments were replicated three times in a randomized block design. After the residues had been incorporated, pigeonpeas were sown on 28-6-76 in black soil (cv. ICP-1) and on 25-6-76 in red soil (cv. ST-1). At the time of harvest, yield and yield components were recorded. In red soil some of the plants were affected by sterility mosaic disease; these were harvested separately and only the uninfected plants were used for calculation of plot yields; the area was corrected for appropriately. (The sterility mosaic-infected plants had on average only half the dry weight of uninfected plants and gave only one tenth as much yield per plant).

(iii) In part of field ST-1 (black soil) where pigeonpea had been grown in 1975/6, the residues of this pigeonpea crop were treated in three ways, as follows: (i) leaves and roots were both removed (ii) leaves were removed but roots were not removed (iii) neither leaves nor roots were removed. Adjacent areas where no pigeonpea had previously been grown served as controls. Within each treatment from replicate plots (size: 9 x 7 m) of cvs. T-21 and ICP-1 were sown on 28-6-77 in a randomized design. Yield and yield components were recorded at harvest, and the results were analysed statistically as a split plot design (although in fact the main treatments could not be fully randomized because the control plots had to be outside the area in which the previous crop was grown).

Results

(i) Residual effect of a pigeonpea crop on subsequent crops.

The yields and total dry weights of the different crops grown in black and red soils in areas where pigeonpea had or had not been not been grown the previous year are shown in Table 50.

In black soil the area where pigeonpea had previously been grown was more low-lying than the control area and there was a certain amount of waterlogging which may have adversely affected all the kharif crops. However it is very clear that pigeonpea itself was much more severely affected by the pigeonpea residual effect than any of the other crops. There could have been some deleterious effect on the other legumes, but if so it was small by comparison with the residual effect of pigeonpea on pigeonpea itself.

In red soil (Table 50 B) the yields of pigeonpea itself were also reduced, but much less than on black soil. There was little or no adverse effect on the other crops; there may even have been a beneficial effect on the sorghum, millet and castor.

These results indicate that the deleterious residual effect of pigeonpea is much greater on black than on red soil, and that it is much more pronounced on pigeonpea itself than on other crops, i.e. it is more or less specific.

(ii) Effect of the incorporation of pigeonpea residues on the growth and yield of pigeonpeas.

The incorporation of pigeonpea leaves or leaves + roots into the soil had no significant effect on the yield of pigeonpeas in either red or black soils (Table 51). None of the characteristic symptoms of the pigeonpea residual effect were observed and the growth of the plants was normal.

(iii) Effects of the removal of pigeonpea residues on the growth and yield of a subsequent pigeonpea crop.

The growth of the plants in the area where a previous pigeonpea crop had been taken was very poor, although clear differences could be seen between cvs. T-21 and ICP-1 : the former was much more badly affected.

These field observations were in good agreement with the harvest data shown in Table 52. The residual effect was significantly greater on yield per plant, yield per hectare and total dry weight per hectare of cv. T-21 than cv. ICP-1. However within the area where pigeonpea had previously been grown the removal of leaves or both leaves and roots had no significant effect.

Discussion

The data in Tables 51 and 52 show that the harmful residual effect was not caused by pigeonpea residues. The same conclusion was

Table 50. Residual effect of pigeonpea on the yield and total dry matter of subsequent crops on (A) Black and (B) Red soils.

A. BLACK SOIL

Crop	Yield (q/ha)			Total dry weight (q/ha)		
	Control	After pigeonpea	% of control	Control	After pigeonpea	% of control
Pigeonpea	8.4 ± 1.4	0.3 ± 0.2	4	34.3 ± 5.2	1.8 ± 0.5	5
Groundnut	1.9 ± 0.2	1.1 ± 0.3	58	22.2 ± 3.8	17.5 ± 8.2	78
Cowpea	3.7 ± 1.1	1.3 ± 0.6	41	10.6 ± 1.8	4.8 ± 1.8	45
Chickpea	4.4 ± 1.0	1.6 ± 0.6	36	11.3 ± 2.3	4.8 ± 1.3	42
Cotton	7.5 ± 2.4	2.7 ± 0.8	36	29.9 ± 7.9	7.8 ± 1.6	26
Sorghum	18.0 ± 2.4	14.5 ± 6.2	81	67.6 ± 9.0	61.1 ±18.4	90
Pearl Millet	9.0 ± 1.6	4.8 ± 2.3	53	38.9 ± 4.6	26.8 ±10.0	69

B. RED SOIL

	Yield (q/ha)			Total dry weight (q/ha)		
	Control	After pigeonpea	% of control	Control	After pigeonpea	% of control
Pigeonpea	11.6± 3.6	6.7± 3.1	57	61.3±17.6	51.9± 8.7	85
Groundnut	5.7± 2.4	4.9± 1.6	86	46.9± 8.2	45.6±11.0	97
Cowpea	11.8± 2.3	11.8± 1.2	100	45.2± 8.5	40.1± 2.4	89
Sorghum	47.5±13.5	58.1± 7.7	122	130.0±20.9	150.1±18.6	115
Pearl millet	14.5± 5.3	21.9± 4.7	151	54.1±11.5	71.7±18.1	132
Castor	5.5± 0.8	8.5± 0.9	154	22.0± 4.2	34.9± 3.5	159

also reached in a plant-pot experiment in which pigeonpea residues were incorporated into the soil before pigeonpea and other crops were sown. No harmful effects of the residues were observed. Therefore we can conclude with a fair degree of certainty that the harmful residual effect of pigeonpeas is not caused by toxic compounds released during the decomposition of pigeonpea leaves and roots.

Only two other possibilities remain; firstly that a substance secreted by living pigeonpea roots is responsible. Such a substance could not itself be toxic (or else pigeonpea crops would be self-inhibiting) but could break down in time to produce a toxin. If this were the case the residual effect of pigeonpea should have been seen in all fields of similar soil type where pigeonpeas are grown after pigeonpeas. However, in 1976/7 we found that the symptoms were not expressed in all the fields in the ICRISAT farm where pigeonpea was grown after pigeonpea but only in some areas (e.g. ST-1, RW-1, BA-25). Particularly in field M-2 the growth of pigeonpea following a previous crop of pigeonpea was perfectly normal. This would be difficult to explain on the hypothesis that pigeonpeas secreted a toxin-precursor into the soil.

The second possible explanation, specific parasitic nematodes, seems much more likely. The growth of a pigeonpea crop could lead to the multiplication of nematodes on pigeonpea if small numbers of such namatodes were already present in the soil. The lack of the residual effect in field M-2 and elsewhere might then be explained by the absence of the initial inoculum of nematodes: field M-2 was newly reclaimed and was previously under water as part of Manmole Tank.

We found that in plant pot experiments the harmful residual effect was expressed if pigeonpeas were grown in soil taken directly from affected parts of fields; but if the soil was allowed to dry first, the effect no longer appeared. This result could be explained if the putative nematodes were killed by drying; moreover the greater residual effect on black soil than on red might be owing to the fact that the latter dries out more completely during the summer months.

The Pulse Entomology section has already started a nematological investigation of this problem, and in the 1977/8 season we will be carrying out a joint experiment to see if the harmful residual effect is reduced or abolished by the application of nematicides.

Table 51. Effects on yield and total dry matter production of the incorporation of pigeonpea residues into black and red soils.

BLACK SOIL (ST-1)	Cv. ICP-1	
Treatment	Yield (kg/ha)	Total dry weight (kg/ha)
Control	568	2,396
Leaf incorporation	492	2,042
Leaf+Root incorporation	527	1,775
LSD (5%)	307 (NS)	591
CV (%)	25.67	12.59

RED SOIL (RA-26)	Cv. ST-1	
Treatment	Yield (kg/ha)	Total dry weight (kg/ha)
Control	678	4,877
Leaf incorporation	726	5,129
Leaf+Root incorporation	716	3,712
LSD (5%)	408 (NS)	2,061 (NS)
CV (%)	25.48	19.91

Table 52. Yield per plant, yield per hectare and total dry weight per hectare produced by pigeonpeas grown in soil where no previous pigeonpea crop was taken (control) or where pigeonpeas had been grown the previous year; either all pigeonpea residues (-leaves-roots), leaves only (-leaves+roots) or no pigeonpea residues (+leaves+roots) were removed.

	Yield per plant (gms)				
Cultivar	Control	-leaves -roots	+leaves +roots	-leaves +roots	Mean
T-21	16.2	1.0	1.7	1.5	5.1
ICP-1	14.5	5.5	7.3	5.4	8.2
MEAN	15.3	3.2	4.5	3.4	

LSD (5%)		
	Cultivars	: 1.48
	Residues effects	: 1.53
	Cultivars within residue treatment group	: 2.96
	Comparison of means between groups	: 2.56

CV : 29.1%

Contd...Table 52

Yield (q/hectare)

Cultivar	Control	-leaves -roots	+leaves +roots	-leaves + roots	Mean
T-21	8.9	0.2	0.5	0.5	2.5
ICP-1	6.2	2.2	2.8	2.1	3.3
MEAN	7.5	1.2	1.6	1.3	

LSD (5%)	Cultivars	: 0.72
	Residue effects	: 0.92
	Cultivars within residue effect groups	: 1.44
	Comparison of means between groups	: 1.35

CV : 32.2%

Total dry matter (q/ha)

Cultivar	Control	-leaves -roots	+leaves +roots	-leaves +roots	Mean
T-21	29.3	1.2	2.1	2.7	8.8
ICP-1	32.7	7.8	10.6	8.1	14.8
MEAN	31.0	4.5	6.3	5.4	

LSD (5%)	Cultivars	2.58
	Residue effects	3.42
	Cultivars within residue effect groups	5.16
	Comparison of means between groups	4.91

CV : 28.4%

IV.2

EFFECTS OF RATOONING ON SECOND-HARVEST YIELDS

Early and medium-duration cultivars of pigeonpeas can go on to produce a second crop of pods after the first crop has matured (see PPR 1974/5 Chapter I; PPR 1975/6 Section IV.4; and ICRISAT Pigeonpea Breeding Annual Report 1975/6 pp 261-268). This year the second harvest yields on both red and black soils of plants which were ratooned after the first harvest were compared with the yields of controls from which pods were plucked at the time of the first harvest but which were not ratooned (referred to as 'non-ratooned' plants). We also investigated the effects on yield and yield components of different heights of ratooning and of different times of ratooning.

Methods

The cultivars selected for these experiments were No.148 and AS-71-37 both of which were found by the Pigeonpea Breeders in their trials last year to give good yields after ratooning (see Pigeonpea Breeding Annual Report 1975/6, p 265).

In both red (R1) and black (ST-1) soils the plants were sown on ridges 75 cm apart at a plant to plant spacing of 30 cm. The experiments were layed out in split plot designs with the two cultivars in the main plots and ratooning treatments in the sub-plots (sub-plot size: 8 x 9 m). The red soil trial was replicated 4 times; the black soil trials 3 times. The dates of sowing were: red soil 6-7-76; black soil 29/30-6-76. The second yield was harvested in March 1977.

(a) Ratooning trial in red soil:

i) Ratooned (about 60 cm above ground level) at the time of first harvest (18-11-76).

ii) Non-ratooned.

(b) Height of ratooning trial in black soil:

i) Ratooned 10 cm above ground level (on 7-12-76).
ii) Ratooned 30 cm above ground level (on 20-11-76).
iii) Ratooned 60 cm above ground level (on 8-12-76).
iv) Ratooned 90 cm above ground level (on 9-12-76).
v) Non-ratooned (pods picked on 4-12-76).

(c) Time of ratooning trial in black soil:

i) Non-ratooned (first harvest of pods picked from the plants on 5-12-76).
ii) Ratooned before flowering (on 21-9-76, 83 days after sowing) first harvest of pods picked from the plants on 15-1-77.
iii) Ratooned* at 'physiological maturity' of the first of pods (on 18-11-76), above ground level.
iv) Ratooned* at maturity of the first flush of pods, i.e. at normal harvest time (6-12-76).
v) Ratooned* 15 days after (iv) above (on 21-12-76)
vi) Ratooned* 30 days after (iv) above (on 5-1-77).

* height of ratooning: 55-65 cm above ground level.

Results

(a) Yields of ratooned and non-ratooned plants in red soil:

The plots in the fourth replicate of this trial were badly damaged by flooding and waterlogging after a heavy storm; the results from this replicate were omitted from the analysis of data.

The yields from the first harvest (in November 1976) were good (over 1.2 tons per hectare) and considerably higher than on black soil (see below).

The non-ratooned controls produced a second flush of pods sooner than the ratooned plants in which more vegetative growth took place before the second crop was produced.

A mean yield of almost 1 ton/ha was obtained in the second harvest from the non-ratooned controls, which was 80% of the yield in the first harvest (Table 53). The ratooned plants produced a mean yield of 0.5 ton/ha, approximately half of that of the non-ratooned plants. A similar pattern of results was obtained with both cultivars.

There was no significant difference between the first-harvest-yields of the two cultivars, but cv. AS-71-37 gave significantly higher second-harvest yields than cv. No.148 (Table 53).

The 100-seed weights were significantly lower in the second harvest than in the first harvest, and within the second harvest were significantly lower from the ratooned plants than from the non-ratooned plants (Table 53).

Table 53. (A) Yields and (B) 100-seed weights from the first harvest and second harvest from ratooned and non-ratooned plants of cvs. No.148 and AS-71-37 grown in red soil.

A. Yield (Kg/ha)

Cultivar	First yield	Treatment	Second yield		Total yield	
No.148	1207	Ratooned	449	636	1567	1842
		Non-ratooned	882		2118	
AS-71-37	1262	Ratooned	555	861	1787	2122
		Non-ratooned	1167		2456	
MEAN	1235	Ratooned	502		1687	
		Non-ratooned	994		2287	
LSD (5%)	574.4 (NS)		204.7		629.1(NS)	
For cultivars			51.4		237.4	
For treatments within cultivars			72.7		335.7	
For comparison between groups			141.8		470.2	
CV%	12.0		4.3		7.5	

B. 100-seed weight (g)

Cultivar	First harvest	Treatment	Second harvest
No. 148	9.39	Ratooned	7.27
		Non-ratooned	7.91
AS-71-37	9.29	Ratooned	7.24
		Non-ratooned	8.11
MEAN	9.34	Ratooned	7.26
		Non-ratooned	8.01
LSD (5%)			
For cultivars	0.630(NS)		0.645(NS)
For treatments			0.463
For treatments within cvs.			0.655
For comparison between groups			0.623

(b) Height of ratooning trial in black soil:

'The yields obtained at the first harvest were low compared with the yields produced by the same cultivars on red soil. This may at least in part be explained by the poor drainage in the part of field ST-1 where this trial was situated, resulting in waterlogging which affected the growth of the plants during the vegetative phase.

The first harvest yields should not have been affected by the ratooning treatments, since the ratooning was carried out only at the time of harvest. However, by mistake, the 30 cm ratooning treatment was carried out 2½ weeks too early resulting in a significant reduction in the yield (Table 54), and also in a reduced 100 seed weight because this early ratooning involved harvesting immature pods.

During the period between the first and second harvests, many of the plants grew very poorly and their leaves became scorched at the tips. These symptoms of poor growth and leaf bearing were found in distinct patches; in between these patches the growth and yield of the plants were good. These symptoms were found in great majority of the area occupied by this trial and no subplot was completely unaffected. Consequently the second-harvest yields from this trial (and from the Time of Ratooning Trial, described below, which was adjacent to it and similarly affected) were poor, and the coefficient of variation was very high (64%). Preliminary investigations have indicated that these symptoms were due to boron toxicity. Similar symptoms in ratooned or late-planted pigeonpeas have been observed in patches in other black-soil fields on the ICRISAT farm.

The variability in yields and the unhealthiness of the plants resulting from this putative toxic effect means that the results from this trial are of doubtful value. In particular no conclusions can be drawn from the percentage mortality which followed the different ratooning treatments, because the relatively high mortality of the plants in the 'bad patches' may have masked any treatment differences.

However, in spite of the poor growth and poor yields the yield figures for the second harvest show clearly that the highest yields were obtained from the non-ratooned controls, the lowest yields from the plants ratooned at 10 cm, and that the yield derived from the ratooned plants increased with the height of ratooning.

As on the red soil, the non-ratooned plants produced a mature second crop of pods sooner than the ratooned plants, and the time taken to maturity of the second crop of pods increased progressively as the plants were ratooned at lower heights. The non-ratooned plants matured 5-6 weeks earlier than the plants ratooned at 10 cm, and 2-3 weeks earlier than the fastest-maturing ratooned plants, those cut at 90 cm.

Table 54. Effects of height of ratooning on 100-seed weight and yield of cvs. No.148 and AS-71-37 on black soil.

Cultivar & Treatment	Dead plants %		100-seed wt. (g) I Harvest		100-seed wt. (g) II Harvest		Yield (kg/ha) I Harvest		Yield (kg/ha) II Harvest		Yield (kg/ha) Total	
Cv. No.148												
Control	22.3		9.36		8.72		702		263		966	
Ratooning at 10 cm	26.5		9.23		7.27		792		30		823	
Ratooning at 30 cm	28.9	27.3	8.96	9.19	8.31	7.92	418	702	95	125	513	827
Ratooning at 60 cm	31.5		9.38		7.40		820		81		901	
Ratooning at 90 cm	27.4		9.02		7.92		777		154		931	
Cv. AS-71-37												
Control	21.3		9.98		8.92		729		414		1143	
Ratooning at 10 cm	17.1		9.97		7.45		802		47		849	
Ratooning at 30 cm	21.6	18.6	9.17	9.75	8.54	8.39	507	676	208	273	715	949
Ratooning at 60 cm	6.6		9.72		8.48		595		403		999	
Ratooning at 90 cm	26.5		9.92		8.55		747		292		1039	
MEAN												
Control	21.9		9.67		8.81		716		338		1055	
Ratooning at 10 cm	21.8		9.60		7.36		798		38		836	
Ratooning at 30 cm	25.2		9.06		8.43		463		152		614	
Ratooning at 60 cm	19.0		9.55		7.94		708		242		950	
Ratooning at 90 cm	26.9		9.47		8.23		763		223		986	
LSD (5%)												
For cultivars	43.03(NS)		1.526(NS)		0.589(NS)		196.9(NS)		335.3(NS)		178.8(NS)	
For treatments	14.64(NS)		0.611		0.704		102.4		155.2		176.6	
For treatments in cvs.	20.71(NS)		0.863		0.996		144.8		219.5		249.7	
For comparisons between groups	28.16(NS)		1.078		0.937		161.9		256.5		240.1	
SD ±	11.96		0.498		0.575		83.6		26.8		144.2	
CV%	52.1		5.3		7.1		12.1		63.8		16.24	

The plants ratooned at 30 cm, because they were ratooned too early by mistake, produced a mature second crop sooner than the other ratooned plants.

The 100-seed weights of the second crop were highest in the non-ratooned plants, lowest in the 10 cm ratooned plants and intermediate in the others, with the exception of the plants ratooned early at 30 cm, where the 100-seed weight was more than in the other ratooned plants but less than in the non-ratooned plants.

(c) Time of ratooning trial in black soil:

In this trial, as in the trial described in (b) above, the first harvest yields were poor, probably partly because the plants suffered from waterlogging damage during the monsoon, and the second harvest yield were badly affected by the putative boron toxicity, which affected all the plots.

Because of the poor vegetative growth, in the 'ratooning for fodder' treatment (83 days after sowing) the fodder yields were low (454 kg/ha dry fodder in cv. No.148 and 391 kg/ha in cv. AS-71-37). This treatment delayed the maturity of the first yield of pods by over a month, but the grain yield was not significantly different from that of plants which had not been ratooned before the first harvest (Table 55). The 100 seed weight was, however, significantly increased in these plants (Table 55).

Ratooning at 'physiological maturity' resulted in a significantly reduced yield at first harvest and a significant reduction in 100-seed weight. There was no significant difference in yield at first harvest between the plants harvested at the time of normal maturity (non-ratooned controls and plants ratooned at normal harvest time) and the plants harvested and ratooned 15 and 30 days late.

In the second harvest the highest yields were obtained from the non-ratooned controls, which were the first plants to mature; the second highest yields came from the ratooned plants which matured earliest - i.e. those ratooned at 'physiological maturity' (Table 55). The plants ratooned after 15 and 30 days' delay produced lower yields in the second harvest and the lowest yields of all were produced by the plants which had been ratooned before the first flowering, which resulted in a delay in the production of the second crop.

In general, 100 seed-weights in the second harvest were lower than in the first. The plants ratooned from physiological maturity onwards had significantly lower 100 seed weight in the second harvest than the non-ratooned controls (Table 55).

Table 55. Effects of times of ratooning on 100 seed weight and yield in first and second harvests of cvs. No.148 and AS-71-37.

Cultivar and Treatment	Dead plants %		100 Seed wt.(g) First harvest		100 Seed wt.(g) Second harvest		Yield (kg/ha) First harvest		Yield (kg/ha) Second harvest		Yield (kg/ha) Total	
Cv. No.148												
Control	66.3		8.91		8.16		692		135		828	
Ratooned 90 days after sowing	52.1		9.46		8.30		702		43		746	
Ratooned @ physiological maturity	58.6	49.6	7.81	8.81	7.12	7.59	593	749	106	86	699	835
Ratooned @ harvest	45.9		9.02		7.25		861		99		960	
Ratooned 15 days after harvest	43.5		8.78		8.81		860		81		941	
Ratooned 30 days after harvest	30.8		8.87		7.55		783		52		836	
Cv. AS-71-37												
Control	44.9		9.71		8.72		820		191		1012	
Ratooned 90 days after sowing	30.6		10.28		9.01		817		56		873	
Ratooned @ physiological maturity	72.8	39.0	7.37	9.38	7.67	8.06	525	790	162	125	687	895
Ratooned @ harvest	30.9		9.53		7.67		826		85		911	
Ratooned 15 days after harvest	24.1		9.73		7.67		869		77		946	
Ratooned 30 days after harvest	30.9		9.65		7.60		879		60		939	
MEAN												
Control	55.6		9.31		8.44		756		164		920	
Ratooned 90 days after sowing	41.3		9.88		8.66		760		50		809	
Ratooned @ physiological maturity	65.7		7.59		7.40		559		133		693	
Ratooned @ harvest	38.4		9.28		7.46		844		92		935	
Ratooned 15 days after harvest	33.8		9.26		7.43		865		79		944	
Ratooned 30 days after harvest	30.9		9.26		7.58		831		56		888	
LSD (5%)												
Cultivars	14.66(NS)		0.508		0.521(NS)		166.3(NS)		47.4(NS)		212.8(NS)	
Treatment	15.79		0.287		0.367		149.8		35.9		159.9	
Treatment in a cultivar	22.34		0.406		0.519		211.8		50.7		226.1	
Comparison between groups	21.59		0.445		0.537		209.5		51.7		230.5	
CV%	29.62		2.6		3.9		16.2		31.1		15.4	

Discussion

One clear conclusion emerges from these results: higher second-harvest yields were produced by non-ratooned plants than by plants ratooned in any way. One reason for this may be that the second crop is produced sooner. The ratooning treatments result in a delay in the production of the second crop of pods, and the reduction in second yield caused by ratooning seemed to be related to the delay involved: the 10 cm ratooning treatments gave the greatest delay and the lowest yields; the early ratooning at 'physiological maturity' led to the least delay and higher yields than the plants ratooned at the normal time of harvest. The reductions in yield associated with these delays may be explicable in terms of the greater water stress, and possibly also heat stress, to which the plants are exposed as the soil moisture is progressively depleted, the temperature rises and the relative humidity falls. These conditions seem to have resulted not only in lower yields but also in a progressive reduction in 100-seed weights.

This year the early cessation of the monsoon may have resulted in a much greater moisture stress on the plants than was apparent last year, when the rains were unusually protracted. The differences in moisture status in the post-monsoon period probably led to differences in the physiological behaviour of the plants (see Section II.4). Last year we found in a small-scale ratooning trial with cvs. ST-1 and HY-3C that there was an optimum height of ratooning (about 1 meter) for second-harvest yields which was better than the non-ratooned treatment (see PPR 1975/6 Section IV.4). Perhaps under conditions in which more water is available in the soil, the delay associated with the production of a second harvest by ratooned plants is not so disadvantageous; indeed the greater vegetative development of the ratooned plants may be an advantage. However, even last year (1975/6) in some other preliminary trials on ratooning we found that there was a tendency for the non-ratooned plants to give higher second-harvest yields than the ratooned ones. These results were not included in our last report because the trials were not well managed and the low second harvest yields may partly have been a result of insect damage. There was also a high mortality of the plants in both ratooned and control plots. However, the results take on a new interest in the light of this year's findings and are reproduced in Table 56.

These early cultivars are unlikely to have been under much moisture stress during the development of the second crop of pods, owing to the late rains in 1975. So it may be that even with adequate moisture supply, the yields of non-ratooned plants are higher than those of ratooned plants, in contradiction to the conclusion suggested by the results for cvs. ST-1 and HY-3C reported last year (PPR Section IV, 4) and discussed above. We hope to investigate this further in the 1977/8 season by comparing the second yield of ratooned and non-ratooned plants with and without irrigation.

Table 56. Yields of ratooned and non-ratooned plants of cvs. Pusa ageti and T-21 in red soil (RA-26) in 1975/6. Net plot size 40 m^2; design RCB with 6 replicates.

	Yield in kg/ha					
	T-21			Pusa ageti		
First harvest yield	664			759		
Ratooning treatment	Non-Ratooned	Ratooned	LSD (5%)	Non-Ratooned	Ratooned	LSD(%5)
Second harvest yield	267	176	67.9	218	181	NS

If further experiments confirm this year's results concerning the marked superiority of non-ratooned over the ratooned plants in producing a second crop, the practical agronomic possibilities will depend on the relative costs of the different methods of harvesting the first crop and the value of the extra yield obtainable in the second harvest from non-ratooned plants.

IV.3

PIGEONPEA AS A PERENNIAL CROP

Pigeonpeas are intrinsically perennial and are indeed sometimes grown as perennials by farmers on a small scale, often as 'backyard' plants. It is generally stated that pigeonpea yields fall off after the first year and that this is one of the reasons why pigeonpeas are not more commonly used in perennial cropping systems. However, quantitative data do not seem to be available on second-year or subsequent yields of pigeonpeas, nor do factors which affect the yields in second and subsequent years seem to have been investigated. If it were possible to obtain good yields from pigeonpeas in second and subsequent years, several useful cropping systems could be developed, for example perennial pigeonpea hedges or wind-breaks.

In some of the experimental plots of our kharif 1975 trials in both red and black soils, the plants were ratooned after the first harvest and a second harvest was taken from the ratooned plants. They were then left (without irrigation) and went on to produce a crop during the 1976/7 season. This crop was harvested and the yields were compared with those of the same cultivars planted nearby in the kharif season of 1976.

In a second trial, plants which had been sown at high population-densities in the rabi season of 1975 (see PPR 1975/6, Sections I.3 and IV.6) were left in the field (without irrigation) after harvesting the pods. These plants produced another crop during the 1976/7 season. The yields were compared with those of nearby plots of the same cultivars planted in the kharif of 1976.

The times of planting and harvesting in these two trials are indicated diagramatically in Table 56a.

Table 56a. Diagramatic representation of the times of planting and harvest of the kharif-kharif and rabi-kharif perennial trials and of the normal kharif crop (control).

		Season	Trial-I	Trial-II	Trial-III (control)
1975	June				
	July				
	Aug.	Kharif			
	Sept.				
	Oct.				
	Nov.				
	Dec.	Rabi	← First harvest & ratooning		
1976	Jan.				
	Feb.			Rabi crop harvest	
	Mar.				
	Apr.	Summer	Ratoon harvest		
	May				
	June				┬
	July	Kharif			
	Aug.				
	Sept.				
	Oct.				
	Nov.				
	Dec.	Rabi	Harvest	Harvest	| Harvest
1977	Jan.				
	Feb.				
	Mar.				

Methods

The times of sowing and spacing of crops planted in the kharif and rabi seasons of 1975 in fields ST-1 (black soil) and RA-26 (red soil) are given in PPR 1975/6. The control plots containing the same cultivars which were used in the 1975 kharif and rabi sowings were planted in the same fields in kharif 1976 on 75 cm ridges at 30 cm plant-to-plant spacings. On red soil (RA-26) cvs. ST-1 and HY-3C were sown in 7 x 7.5 m plots (3 replicates per cultivar, completely randomized design) on 25-6-76; in black soil (ST-1) the controls for trial I (cvs. ICP-1, ST-1 and HY-3C) were planted in four replicates in a completely randomized design, with plot size 7 x 7.5 m. For trial II four replicates of the controls (cvs. T-21, ST-1, 7065) were sown in a completely randomized design with plot size 10 x 6.75 m. The planting date was 28-6-76.

Yield and yield components were recorded at harvest (December 1976-February 1977). Because the plots of the perennial pigeonpeas and of the controls could not be layed out in a randomized or split plot design (since the perennial plots were already in the field) the results could not be analysed by the standard procedures. Instead data are given as mean values for the replications within a treatment, with standard deviations.

Results and discussion

(i) Trial I:

In the plots of perennial pigeonpeas in trial I the stands were reduced by the wilt disease, which killed plants both before and after the first harvest at the end of the 1975 season; further attacks of the disease occurred during 1976 season. Yields per plant as well as yields per hectare are shown in Table 57.

In the red soil, many of the plants of cv. ST-1 were severely affected by the sterility mosaic disease which resulted in a low average yield per plant and yield per hectare. However cv. HY-3C is resistant to this disease and there were fairly high yields per plant. The yields per hectare were also quite good, and higher than those of the controls (June 1976 planting). The latter were extraordinarily low, no doubt partly because of the moisture stress which led to low yields in all our trials; the perennial plants may have had a relative advantage under these circumstances since they flowered and podded several weeks earlier than the controls and may therefore have been less affected by the moisture stress.

Table 57. Yields at harvest in January 1977 of pigeonpeas planted in June-July 1975 and June 1976.

Cultivar	Planting	Yield/plant (g)	Yield/ha (q)
		RED SOIL	
HY-3C	July 1975	42.0 ± 22.7	7.6 ± 5.4
	June 1976	9.4 ± 4.7	4.4 ± 2.4
ST-1	July 1975*	7.0 ± 2.7	2.2 ± 1.4
	June 1976	25.0 ± 5.1	11.6 ± 3.6
		BLACK SOIL	
HY-3C	June 1975	5.0 ± 2.1	0.6 ± 0.2
	June 1976	5.2 ± 1.1	2.2 ± 0.5
ICP-1	June 1975	7.5 ± 4.6	2.5 ± 1.7
	June 1976	14.5 ± 2.1	6.2 ± 0.9
ST-1	June 1975	11.3 ± 4.0	1.7 ± 0.8
	June 1976	12.5 ± 2.3	5.2 ± 1.0

* These plants were badly affected by sterility mosaic disease

In the black soil, the growth and yield of the perennial pigeonpeas was poor; on a per hectare basis the yield was between a half and a quarter of that of the first-year crop (Table 57). In this case the low yields per plant could not be explained in terms of sterility mosaic disease because the plants in these trials were not infected.

These plants were growing in the same field (ST-1) where the severe harmful residual effect of pigeonpea on subsequent crops of pigeonpea was found (see PPR 1975/6 Section IV, 1 and this report Section IV.1). It seems very likely that the same deleterious effect was expressing itself in the perennial crop. This deleterious residual effect (which is probably caused by a build-up of parasitic nematodes) was much less pronounced on red soil.

These results indicate firstly that if pigeonpeas are to give reasonably good yields as perennials, wilt and sterility mosaic resistance would be necessary, and secondly that perennial pigeonpea cultivation may not be very successful in soils in which a build-up of parasitic nematodes occurs.

(ii) Trial II:

The yields which were harvested in December 1976-February 1977 from the normal 1976 kharif plantings and from the plots which had been planted in the 1975 rabi season are shown in Table 58.

The 1975/6 rabi crop planted in November 1975 had much higher population densities than usual and these plants were very crowded during the kharif season 1976, hence the lower yield per plant than in the normal 1976 kharif plantings at wider spacings. However the yields per hectare in all cases were about the same.

A pigeonpea crop sown at high population densities at the beginning of the rabi season can give good yields (see Section IV.4). The results presented above indicate that such plants after surviving the dry summer season can go on to give a yield in the subsequent kharif season which is comparable to that of a normal kharif-sown crop.

The crop was harvested late (from December 1976 onwards) but the early cultivars BS-1 and T-21 planted in November 1975 produced a mature crop much earlier than this, before the end of the kharif season.

Table 58. Yields at harvest (in December 1976-February 1977) of pigeonpeas planted in November 1975 and June 1976 (in black soil).

Cultivar	Planting	Yield/plant (g)	Yield/ha (q)
T-21	November 1975	7.6 ± 2.0	7.6 ± 0.9
	June 1976	16.3 ± 3.4	8.9 ± 2.1
ST-1	November 1975	5.1 ± 0.8	5.2 ± 1.5
	June 1976	12.5 ± 2.3	5.2 ± 1.0
ICP-7065	November 1975	5.9 ± 0.5	5.7 ± 0.2
	June 1976	12.2 ± 1.5	5.3 ± 0.4
BS-1	November 1975	10.2 ± 2.1	7.7 ± 0.1

This suggests a possible cropping pattern involving early or early-medium cultivars as follows: rabi pigeonpea crop left after harvest to give a kharif pigeonpea crop, harvested at the end of kharif season, followed by some other rabi crop. This could be of use in situations where at present black soil is left fallow in the kharif because of the difficulty of working the soil after the onset of the monsoon.

The high population densities used in the rabi plantings mean that if some of the plants die for pathological or physiological reasons before or after the harvest of the rabi crop, the population may still be more than adequate to give a good yield in the kharif season, during which the plants grow much larger.

The further possibility of ratooning such plants during the kharif season for fodder was investigated in a preliminary trial. Green fodder yields of 11 tons/ha fresh weight (3.5 tons/ha dry weight) were obtained by ratooning in early August 1976; the subsequent grain yield was delayed compared with non-ratooned controls, but not reduced. However during these small preliminary trials on ratooning in the kharif season, we found that such ratooning was successful only if there was little or no rain during a period of a week or so following the ratooning. When plants were ratooned a day or two before there was heavy rain, almost all of them were killed. These plants were examined by the Pulse Pathologists who could find no evidence that the plants died of wilt or other diseases; it is probable that ratooning made the plants very susceptible to waterlogging damage.

IV.4

PIGEONPEA AS A RABI CROP

Last year we found that pigeonpeas could be grown successfully as a non-irrigated rabi crop at high plant populations (see PPR 1975/6 Section IV.6). This year we carried out a trial with cultivars from the early, medium and late duration groups, at 4 spacings representing plant populations between 12.5 and 100 plants per square meter.

Methods

Cultivars Pusa ageti and T-21 (early), ICP-1 and C-11 (medium) and NP(WR)-15 and ICP-7065 (late) were grown at four spacings, 20 x 5 cm (100 plants/m^2), 28 x 7 cm (50 plant/m^2), 40 x 10 cm (25 plants/m^2) and 57 x 14 cm (12.5 plants/m^2) in a split plot design (4 replications) with cultivars in the main plots and spacings in the sub-plots. The sub-plot size was 5 x 4 m. The trial was sown in deep black cotton soil (vertisol) in field B-5 on 20-10-76. The field had been fertilized with phosphorus (50 kg/ha P_2O_5) and zinc (22 kg/ha $ZnSO_4$), which were broadcast and incorporated at the beginning of the monsoon season. The soil was left fallow during the monsoon. After sowing the trial received one light sprinkler-irrigation to ensure uniform germination. Thereafter no irrigation was given. Hand weeding was carried out as and when required and the crop was protected against pest attack by sprays of endosulphan.

Within a given cultivar, counts were made of the number of plants bearing flowers, starting soon after flowering began. These counts were taken every two or three days until most of the plants were flowering. The data at which 50% of the plants were flowering was estimated from these data.

The plants were harvested on the following dates:

T-21, 1-3-77; Pusa Ageti, 2-3-77; C-11, 3-3-77; ICP-1, 4-3-77; ICP-7065 and NP(WR)-15, 11-3-77. At the time of harvest, stem weights, pod weights and seed weights from each plot and the fallen leaves from each plot were collected and weighed. All weights at harvest were corrected to oven-dry weights on the basis of the difference between the weight at the time of harvest and the oven-dry weight of subsamples.

From subsamples of 10 plants per plot the pods were removed, the branches were separated from the main stems and the weight of branches and main stems were taken, and the pods and seeds were counted. From these data the pod number per plant and seed number per pod were calculated and also the percentage of total stem dry weight which was

made up of branches and of main stems. The scars on the racemes, representing abscission zones of fallen buds, flowers and pods, were counted and from these data the percentage of pod set was calculated, as below:

$$\text{Percentage pod set} = 100 \times \frac{\text{Pod number per plant}}{\text{Scar number per plant} + \text{Pod Number per plant}}$$

Results and Discussion

The plants in this trial grew well. Although many of the plants had small dark patches on their stems which were identified by the Pulse Pathologists as symptoms of bacterial stem canker, the crop looked very healthy.

(i) Days to flowering:

There was little or no effect of the population-densities on the dates of 50% flowering. The dates for the different cultivars are shown in Table 59. The number of days from sowing to 50% flowering for these cultivars grown during the kharif season are also shown in this Table. Although the relative order of flowering and maturity was more or less the same in the kharif and rabi seasons with the early cultivars earliest and the late cultivars latest, in the rabi season the time-course of development and maturation was telescoped. If we were to apply the classification of durations which is normally used for kharif-grown pigeonpeas, we could say that in the rabi season, 'early' cultivars became extra-early, 'medium' cultivars became early and 'late' cultivars had an early-medium duration (less than 5 months from sowing to harvest). These changes are a consequence of the fact that 'medium' and 'late' cultivars are photosensitive 'short day' plants which flower sooner when they develop under short daylengths; at Hyderabad (latitude 17°N) the shortest daylengths (11 hours) occur during the rabi season, (see ICRISAT Pigeonpea Breeding Report 1974/5 pp. 78-82 and 1975/6 pp. 93-106).

(ii) Yield:

The seed yields are shown in Table 60. The medium and late cultivars yielded significantly better than the early cultivars and cv. C-11 significantly outyielded all the other cultivars. Its mean yield (1710 kg/ha) was considerably higher than any yields obtained from our kharif pigeonpea trials. The mean yield of cv. ICP-1 (1494 kg/ha) exceeded the mean yield of this cultivar grown as a kharif crop in the same field (1244 kg/ha). These figures indicate the considerable potential of pigeonpeas as a rabi crop.

Table 59. Dates at which 50% of the plants first flowered in the rabi and kharif seasons.

Cultivar	A Date of 50% flowering	B Days after sowing of 50% flowering	C Days after sowing of 50% flowering kharif season	D Reduction in days to 50% flowering in rabi compared with kharif (C-B)
T-21	30-12-76	71	86	15
Pusa Ageti	5-1-77	77	89	12
C-11	8-1-77	80	125	45
ICP-1	10-1-77	82	116	34
7065	25-1-77	97	162	63
NP(WR)-15	27-1-77	99	155	56

Table 60. Yields of six cultivars of pigeonpea grown at four plant populations in the rabi season.

Yield (Kg/ha)

Cultivar	Populations (Plants/m^2) 100	50	25	12.5	Mean
T-21	911	979	1236	1143	1067
Pusa ageti	1036	1111	1060	1102	1077
C-11	1785	1580	1599	1875	1710
ICP-1	1374	1470	1535	1598	1494
7065	1260	1365	1456	1549	1408
NP(WR)-15	1095	1253	1399	1387	1284
Mean	1243	1293	1381	1442	
	Overall mean		1340		
			LSD	SE±	CV%
Cultivars			183.6	86.1	18.1
Spacings			77.8	38.8	10.0
Spacings in a cultivar			190.6	95.1	
Comparison between groups			238.9	119.2	

Last year also we found that higher yields were obtained with medium and late than with early cultivars. The yields obtained last year were much lower than this year, probably because last year's rabi crop was planted late (on 11-11-75). This year the Farming Systems group found that delayed sowings of rabi pigeonpea resulted in reduced yields (see ICRISAT Farming Systems Report 1976/7).

The highest mean yield was produced by the lowest plant population (12.5 plants/m^2); this was significantly greater than the yields at populations of 50 and 100 plants/m^2. A similar pattern was found within the individual cultivars where in all cases except in cv.Pusa ageti significantly higher yields were obtained at lower plant populations. However the differences in yield were not great: the overall mean yield at 12.5 plants/m^2 was only 16% greater than at 100 plants/m^2 in spite of an 8-fold difference in plant population. This indicates that the plants had a considerable 'plasticity' in that they are able to adjust to a wide range of spacings with relatively little change in yield. This was also found in 'fan' plantings in the rabi season (see Section III.1). In cv. Pusa ageti this adjustment was more or less complete.

If rabi sowings are delayed, the growth of the plants is likely to be reduced. In such a case the optimum plant populations may be higher than those for early rabi sowings. Last year, when the rabi pigeonpeas were sown in mid-November, we found that significantly higher yields were obtained with 22 plants/m^2 than with 13 plants/m^2,

(iii) Dry matter production:

The amount dry matter in the above-ground parts of the plants at the time of harvest was greatest in the late cultivars, less in the medium cultivars and least in the early cultivars (Table 61). The same pattern was found when the fallen leaves were taken into account. The cultivar which produced the highest total amount of dry matter, including fallen leaves, was cv. 7065 (7098 kg/ha). The shoot dry weight at harvest and the total dry matter produced by cvs. ICP-1 and C-11 were similar to each other. A comparison of these figures and the yields of the different cultivars reveals that yield and dry matter production were not closely related. The greater yield of cv. C-11 than of cv. ICP-1 or of the late cultivars was associated with a significantly higher harvest index (Table 61). The same ranking of harvest indices was found when the harvest index was corrected to take into account the fallen leaves (Table 61).

There was no significant effect of plant population on shoot dry weight at harvest (Table 61). However there was a significantly greater

Table 61. Yield, shoot dry weight, dry weight of fallen leaves, total dry weight and harvest index uncorrected and corrected for leaf fall of pigeonpeas grown in the rabi season.

	Kg/ha					
	Yield	Shoot D.W.	Fallen leaves	Total D.W.	Harvest Index	H.I.Corrected for leaf fall
CULTIVARS						
T-21	1067	3489	1045	4534	30.6	24.1
Pusa ageti	1077	3356	917	4274	32.2	25.4
C-11	1710	4932	1365	6297	35.1	27.2
IC-1	1493	4827	1198	6026	31.1	24.9
IC-7065	1408	5492	1605	7098	25.8	20.0
NP(WR)-15	1284	5774	911	6685	22.2	19.3
LSD (5%)	183.6	610.6	433.2	875.9	2.41	2.64
SE±	86.2	286.4	203.3	411.1	1.14	1.23
CV%	18	17	49	20	11	15
POPULATIONS: (Plants/m^2)						
100	1243	4658	1291	5949	26.9	21.3
50	1293	4704	1274	5978	28.2	22.1
25	1381	4654	1119	5774	30.7	24.3
12.5	1442	4563	1011	5574	32.2	26.4
LSD (5%)	77.8	232.5	194.4	318.7	1.33	1.29
SE±	38.8	115.9	96.9	158.9	0.66	0.64
CV%	10	9	29	10	8	10

mass of fallen leaves at the higher populations than at the lowest plant population, and as a consequence the total dry weight (shoots+fallen leaves) was higher at the higher plant populations (Table 61). On the other hand the yield at the populations of 100 and 50 plants/m^2 was significantly lower than at the populations of 25 and 12.5 plants/m^2. This effect of spacing on dry matter production and yield is clearly reflected in the harvest indices, both before and after correction for fallen leaves: the harvest indices declined significantly as the plant population increased. The same pattern was found within the individual cultivars as was shown by these overall means.

(iv) Branching:

A quantitative measure of branching was provided by the weight of the branches expressed as a percentage of the total stem weight. There were significant differences between cultivars in their branching (Table 62) with cv. ICP-7065 producing the higher proportion of branches and Pusa ageti the lowest. There was no significant difference between cvs. C-11 and ICP-1 in this respect.

Table 62. Percentage of total stem dry weight in the branches at the time of harvest of six pigeonpea cultivars grown in the rabi season at four plant populations.

Percentage of stem dry weight in branches

Cultivar	Populations (plants/m^2)				Mean
	100	50	25	12.5	
T-21	24.8	30.5	38.5	42.0	33.9
Pusa ageti	17.8	21.5	30.0	37.3	26.6
C-11	30.8	34.3	44.0	52.8	40.4
ICP-1	33.0	34.5	42.3	54.8	41.1
ICP-7065	36.8	39.5	47.5	59.8	45.9
NP(WR)-15	33.5	31.5	42.8	49.3	39.2
Mean	29.4	32.0	40.8	49.3	
	Overall mean		37.87		
			LSD(5%)	SE±	CV%
Cultivars			2.58	1.21	9.0
Spacings			2.84	1.41	12.9
Spacings in a cultivar			6.96	3.47	
Comparison between groups			6.50	3.24	

The plants at the lowest population density had the highest proportion of branches which made up nearly half the total stem weight (Table 62). There was a significantly lower proportion of branches as the population-density increased. This agrees with the results of the spacing studies in 'fan' plantings described in Section III.1.

A similar pattern of response to spacing was found within each cultivar, and at the different population-densities the relative differences between the cultivars were similar. For example cv. Pusa ageti had the lowest proportion of branches and cv. 7065 the highest at all population densities (Table 62).

(v) Pod set, seed set and 100 seed weight:

The percentage of pod set was not significantly correlated with yield (r = 0.15). This percentage was highest on the late cultivars (Table 63) possibly because the increasing moisture stress during their reproductive phase led to an early cessation of flowering, and hence fewer infructuous flowers were produced. There was no significant influence of spacing on percentage pod set.

Table 63. Percentage pod set, seed number per pod and 100 seed weights produced by pigeonpeas grown in the rabi season.

	% Pod set	Seeds/pod	100 Seed wt.(g)
CULTIVARS:			
T-21	15.1	2.00	5.6
Pusa ageti	15.0	2.29	6.8
C-11	16.9	2.89	6.8
IC-1	15.6	2.75	6.2
IC-7065	18.6	2.30	5.3
NP(WR)-15	19.0	2.26	5.5
LSD (5%)	2.18	0.193	0.22
SE+	1.02	0.091	0.10
CV%	17	11	5
POPULATIONS (Plants/m^2)			
100	16.5	2.28	6.1
50	16.4	2.35	6.1
25	16.9	2.53	6.0
12.5	16.9	2.51	6.0
LSD(5%)	1.53	0.143	0.16
SE+	0.76	0.071	0.08
CV%	16	10	5

The seed number per pod and 100-seed weights differed between the different cultivars (Table 63). There was a tendency for 100-seed weight to decline as the plant population decreased, but this was not significant at the 5% level. There was a converse tendency for seed number per pod to increase as the population decreased and in this case the two lower populations had significantly more seeds per pod than the two higher populations (Table 63).

The 100 seed weights produced by the rabi crop were lower than those produced by the same cultivars grown as a kharif crop (Table 64). The reductions were greatest in the medium and late cultivars. Similar reductions in 100-seed weights were observed in last year's rabi crop (see PPR 1975/6 Section IV.6).

(vi) Seed quality and palatability:

The seeds from kharif and rabi crops of ICRISAT-1 were compared with respect to the recovery of dhal after milling and the cooking time and palatability of the dhal.

The seed was milled in a local village mill using local methods. The percentage recoveries of normal dhal were 73.3% and 71.4% for the kharif and rabi crops respectively. When the broken pieces of dhal were included the recoveries were 78.0% and 76.5% respectively.

Samples of these two lots of dhal were supplied to 24 members of the ICRISAT staff, including both scientists and labourers, for cooking and palatability tests. (The samples were numbered and the respondent did not know which sample of dhal was which). Some respondents claimed that the kharif dhal took longer to cook, others claimed the rabi dhal took longer, and some found no difference. A majority of the respondents preferred the taste of the dhal from the rabi crop.

We found last year that seeds of the same cultivar, ICP-1 contained a very similar percentage of protein when grown as a kharif and a rabi crop (PPR 1975/6 Table 35).

From all these results we can conclude that there was not much difference between the seed from the rabi and kharif crops from the point of view of dhal recovery on milling, quality and acceptability.

Table 64. 100 seed weights produced in the kharif and rabi seasons 1976/7.

Cultivar	100 seed weight (g)		
	Kharif Crop	Rabi Crop	Rabi as % of Kharif crop
T-21	5.7	5.6	98
Pusa ageti	8.0	6.8	85
C-11	9.2	6.8	74
ICP-1	8.3	6.2	75
ICP-7065	7.0	5.3	76
NP(WR)-15	7.8	5.5	71
MEAN	7.7	6.0	78