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PULSE PHYSIOLOGY

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PART II

CHICKPEA PHYSIOLOGY

by

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PULSE PHYSIOLOGY

Staff 1974/75

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## Preface

The report covers the first season's research (rabi 1974/5) carried out at ICRISAT on chickpea physiology. Much of the work reported here was preliminary and should help to provide background information for future investigations.

An off-season crop was grown in the Lahaul Valley, Himachal Pradesh from May to October 1975 and in the rabi season 1975/6 field experiments are being carried out both at the ICRISAT site, Hyderabad and at Hissar, Haryana. The results of this work will be presented in our 1975/6 report.

A comprehensive anatomical study of chickpeas was begun in 1975 and is continuing; the results will be presented separately and systematically within a year or two.

This report is not in any way a formal publication or an official document of the Institute. It is intended for limited circulation only and should not be cited.

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## Abbreviations

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.

NAR = Net Assimilation Rate =  $\frac{\text{Dry Weight gained in time } t_2-t_1}{\text{Average Leaf Area during } t_2-t_1}$

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

RGR = Relative Growth Rate =  $\frac{\text{Increase in Dry Weight in time } t_2-t_1}{\text{Dry Weight at time } t_1}$

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

CHAPTER I  
THE ANALYSIS OF GROWTH AND YIELD

Introduction

The objectives of growth analysis are to understand the growth and development of the crop throughout the period of crop growth and also to identify and understand the differences between cultivars. In practical terms, the former could help in understanding, improving and developing cultural practices which increase the yield per unit area; the latter could be of value for varietal improvement by breeding.

In the rabi season 1974/5 the growth and development of five cultivars of different duration and plant type were investigated using the methods of growth analysis. The nitrogen content of the various components of the plants throughout the growing period was also determined. At the time of harvest the yield and yield components were recorded in detail. In addition, non-destructive observations were made on selected plants at weekly intervals throughout the growing season, and these plants were also photographed regularly.

The purpose of these observations was to build up a body of quantitative information which should provide a foundation for our future work on the physiology of the crop.

Methods

Three early cultivars (JG-62, BEG-482 and Chaffa), two mid-late (850-3/27 and L-550) and two late cultivars (T-3 and G-130) were used. Cv L-550 is a "Kabuli" and the others are "desi" types. JG-62 is a

"double-podded" cultivar.

They were sown on black soil in the ST-1 area of the Farm on 1-10-1974. The soil had been left fallow during the monsoon season. Before sowing,  $ZnSO_4$  (45 kg/ha) and phosphate (80 kg/ha as  $P_2O_5$ ) were broadcast and incorporated by tractor. No nitrogenous fertilizers were used and the crop was not irrigated at any stage.

Plot sizes were 6 x 8 M and plant-to-plant spacings 30 x 10 cm. Sowing was done by hand at a depth of 5 cm in furrows opened immediately beforehand by tractor. Two seeds were sown per hill and later the seedlings were thinned out to one plant per hill. A Randomized Block design was used with two replications.

Both destructive and non-destructive growth analysis were performed on cvs JG-62, 850-3/27, L-550, T-3 and G-130. For destructive growth analysis five plants with average growth were sampled at weekly intervals. The plants were separated into their component parts i.e., pinnae, stipules, rachis, stem and at later stages of growth into flowers and pods. In early stages of growth the pinnae were blueprinted for recording their area; at later stages of growth the pinna area was recorded by an Automatic Area Meter Model AAM 7, Hayashi Denkoh Co., Ltd. Leaf area was recorded on all five plants in two replicates. Plant height, number of branches, number of active and senescent leaves and number of flowers and pods were recorded. The different components were dried in an oven at 80°C and the dry weights were taken. These samples were then ground to powder and analysed in the Central Analytical Laboratory (Section Head: Dr. R. Jambunathan) by Mr. G. Ravi Kumar

for percentage nitrogen content by the macro- and micro-Kjeldahl method.

Simultaneously a non-destructive growth analysis was performed on ten selected plants week by week. The height, branch number, branch length, number of leaves on the mother shoot and branches, position of first flower and position of first pod were all recorded. Biweekly photographs were taken of three plants in each replicate of all the cultivars to record the morphological changes in crop growth with advancing age.

The analysis of yield and its components was carried out branchwise. Each sample consisted of 100 plants which were uprooted from each plot; thus two replicate samples were obtained for each cultivar. Roots were separated from the rest of the plant at the point of insertion of the cotyledons; pods were separated branchwise and were counted and weighed after drying in an oven at 80°C. They were threshed and seed number and seed weight were recorded. The number of seeds per pod and 100 seed weight were calculated from these results.



1. ANALYSIS OF GROWTHResultsA. Morphological ObservationsBranches

The number of primary, secondary and higher order branches was counted in 100 plants from each plot at the time of harvest. The average branch numbers per plant are shown in Table 1. (The pod numbers and yield on these branches were also recorded: see Fig. 6).

Table 1. Number of Primary, Secondary and Tertiary branches per plant at the time of harvest (Average of 200 plants)

Cultivar	Primary branches	Secondary branches	Tertiary branches	Quaternary branches	Total
JG-62	5.2	2.7	0.1	-	8.0
BEG-482	4.1	7.5	3.9	0.13	15.6
Chaffa	4.5	5.5	0.5	-	10.5
850-3/27	3.7	3.9	0.2	-	7.8
L-550	4.1	7.3	1.7	0.01	13.1
T-3	3.8	5.3	1.3	-	10.4
G-130	3.6	5.8	2.3	0.13	11.8

There was no apparent relationship between the numbers of primary and secondary branches. Thus JG-62 had most primary branches but fewest secondary; 850-3/27 had approximately equal numbers of primary and secondary branches, while the remaining cultivars had more secondary than primary branches.

On the other hand there was a general tendency for cultivars with more secondary branches to produce more tertiary and higher order branches. This is indicated by the data for cvs BEG-482, L-550 and G-130. These cultivars are of early, medium and late maturity respectively. The greater production of branches is therefore not simply explicable in terms of the length of the vegetative phase; in fact the maximum number of secondary and higher order branches were produced by BEG-482 which had one of the shortest vegetative phases.

### Leaves

The production of new leaves on the mother shoots and branches took place at a more or less constant rate throughout the vegetative phase and during the earlier part of the reproductive phase. Data showing the number of nodes on the mother shoots of cvs JG-62, 850-3/27, L-550, T-3 and G-130 are shown in Fig. 1. Only in the latter two, which are late-maturing, did the growth of the mother shoots continue up to the time of harvest.

The rate of appearance of new leaves was rather higher in JG-62 than in other cultivars. During the period from 20 to 60 days after

sowing the average number of days between the successive appearance of new leaves (i.e., the plastochron) for the different cultivars was as follows:

JG-62	2.1 days
850-3/27	2.3 days
L-550	2.5 days
T-3	2.4 days
G-130	2.5 days

In Fig. 1 the total number of active (i.e., green) leaves per plant is also shown. In cvs JG-62, 850-3/27 and L-550 the decline in total leaf number per plant, owing to the senescence and falling of leaves, began at around the time that the growth of the mother shoots ceased. But in the late cultivars T-3 and G-130 a net decline in leaf number took place while new leaves were still being formed.

Data on the leaf area index (LAI) throughout the growth period are shown in Fig.2 and at the time of flowering in Table 2. Not surprisingly, the longer the vegetative phase, the greater the LAI which had been reached by the time of flowering. In all cultivars the maximum LAI was achieved after flowering (Fig. 2; Table 2) but in the late cultivars the LAI began to decline 1-2 weeks after flowering whereas in the other cultivars this decline began 3-4 weeks after flowering.

The leaf area durations (LAD) were related to the duration of growth of the different cultivars. LAD was least in JG-62 and most in T-3 (Table 3).

FIGURE 1

CHANGE WITH TIME OF NODE NUMBER ON MAIN STEM AND TOTAL ACTIVE LEAF NUMBER PER PLANT

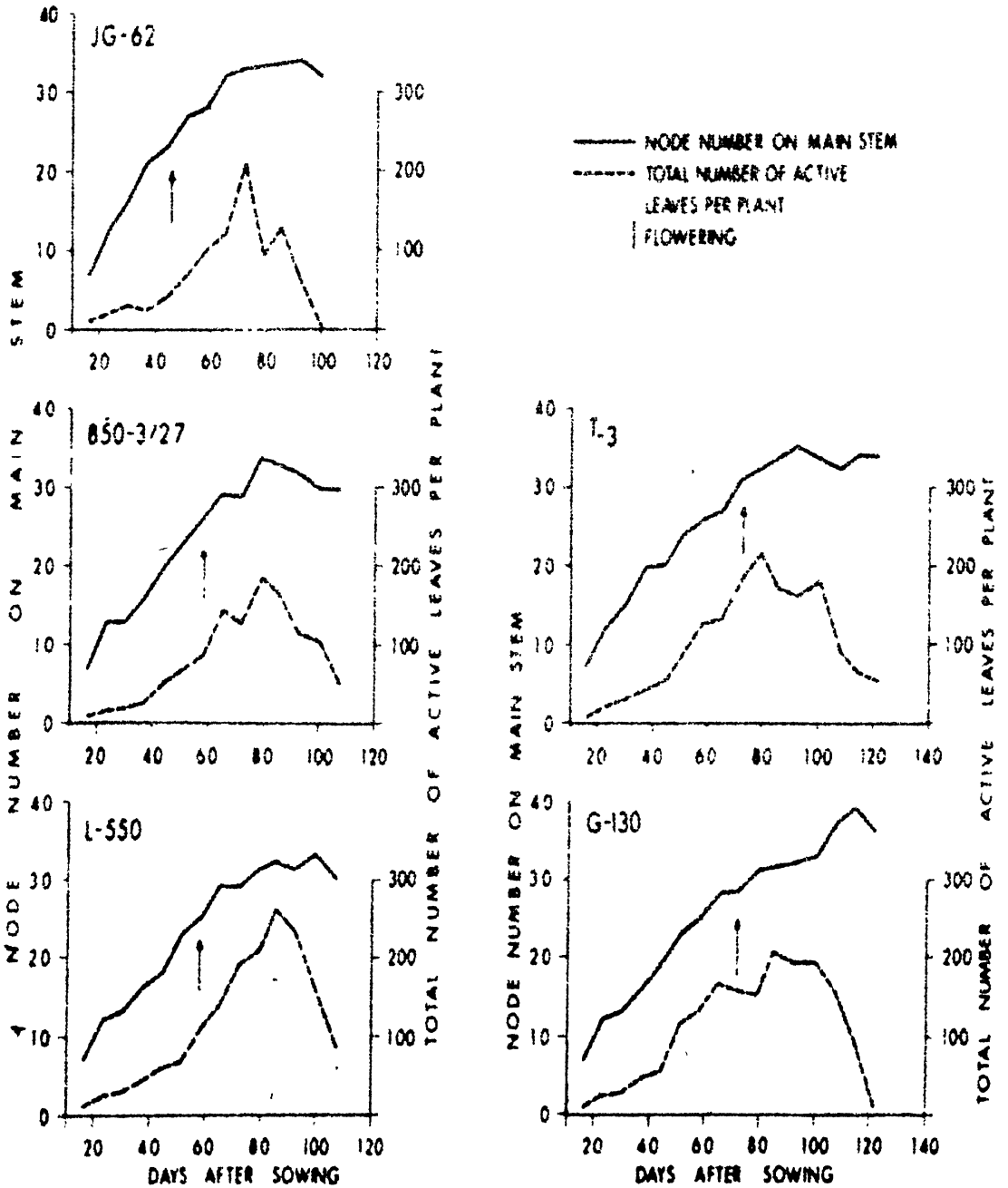


FIGURE 2

CHANGE IN LEAF AREA INDEX AND POD NUMBER PER PLANT WITH TIME

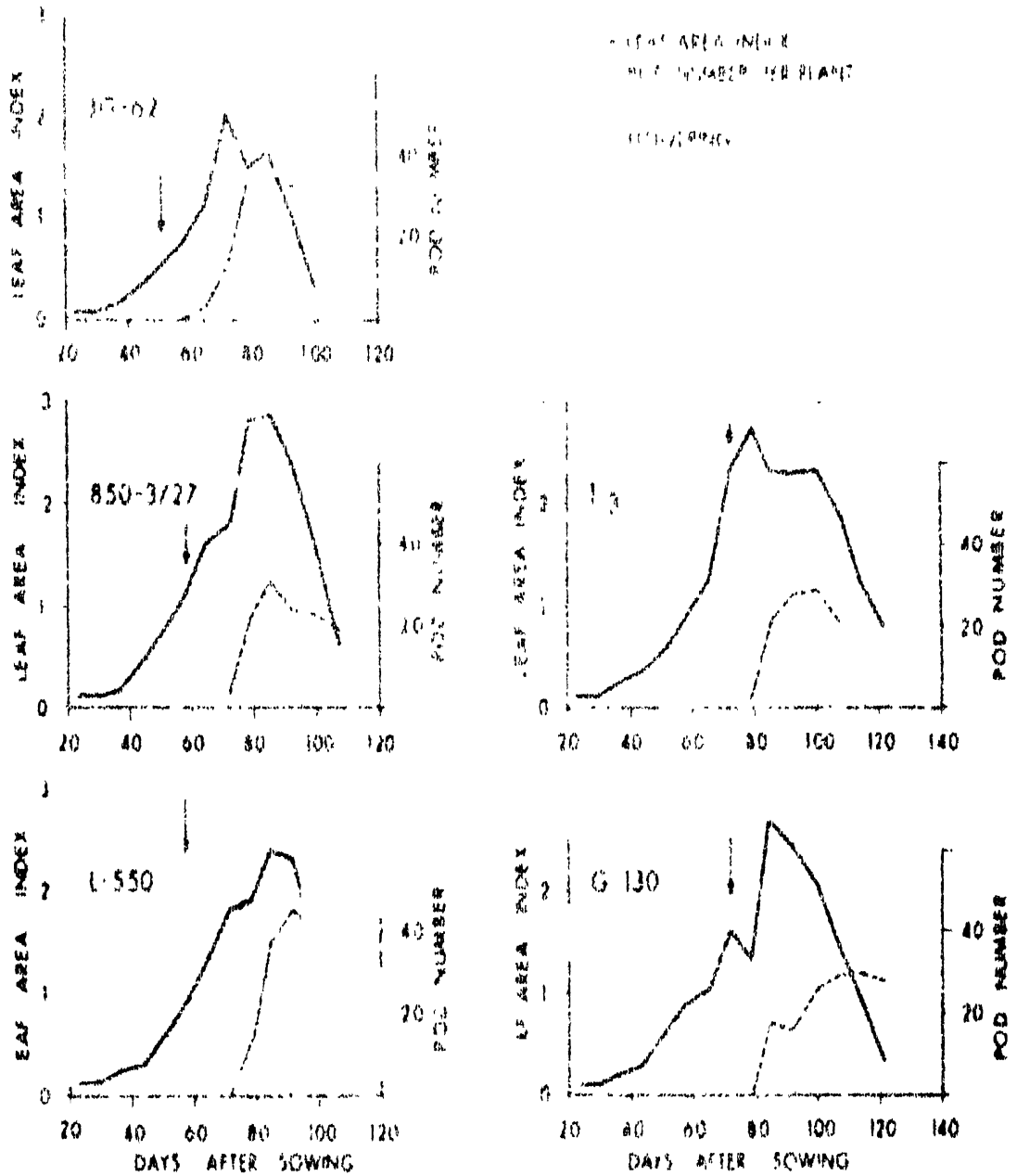


Table 2. Leaf Area Index (LAI) at the time of flowering and at the time of maximum LAI

Cultivar	AT FLOWERING		M A X I M U M			
	Days after sowing.	LAI	Days after sowing	Days after flowering	LAI	Days to harvest
JG-62	51	0.6	72	+ 21	2.1	100
850-3/27	58	1.1	79	+ 21	2.9	107
L-550	58	0.9	85	+ 27	2.4	107
T-3	72	2.4	79	+ 7	2.7	121
G-130	72	1.6	85	+ 13	2.7	121

Table 3. Leaf Area Duration (LAD) of different cultivars.

Cultivar	LAD (Weeks)
JG-62	9.8
L-550	14.4
850-3/27	16.3
G-130	16.0
T-3	19.4

In all cultivars the mean specific leaf weight (SLW) of the green leaves showed an increase during the reproductive phase followed by a fall (Fig. 3). Around the time of flowering all five cultivars had a similar SLW (4.0 - 4.4 mg/cm<sup>2</sup>).

In all cultivars the relative weights of the rachis and pinnae changed during development; the rachis to pinna ratio fell after the first 30 days and then remained more or less steady until the later part of the reproductive phase when there was a steep rise in this ratio (Fig. 4).

The cultivars differed in their rachis : pinna ratios. This ratio was generally highest in cv L-550 and lowest in cv 850-3/27. The rise in the rachis : pinna ratio towards the end of the reproductive phase is largely explicable in terms of the fall of pinnae from senescent leaves. Most of the rachis of such leaves remained attached to the plants.

#### B. Dry Matter Production

The progressive accumulation of dry matter with time in cvs JG-62, 850-3/27, L-550, T-3 and G-130 and the distribution of this dry matter between stems, leaves and reproductive structures is shown in Fig.5.

The pattern of dry matter accumulation follows the familiar form of growth curves; slow growth initially, a "grand period" of more rapid growth and then a slowing down and cessation of growth.

FIGURE 3  
 CHANGE IN SPECIFIC LEAF WEIGHT  
 WITH TIME

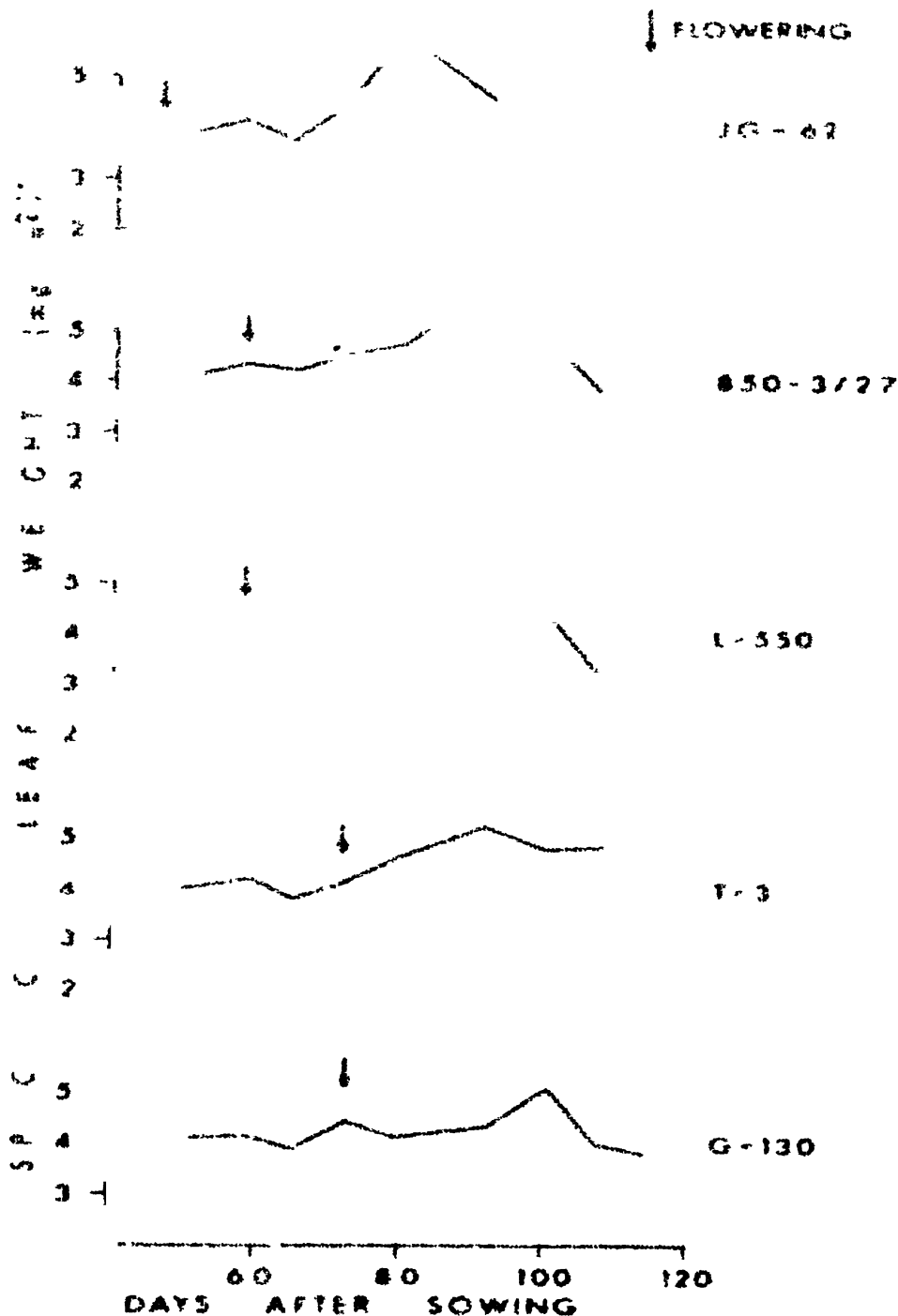
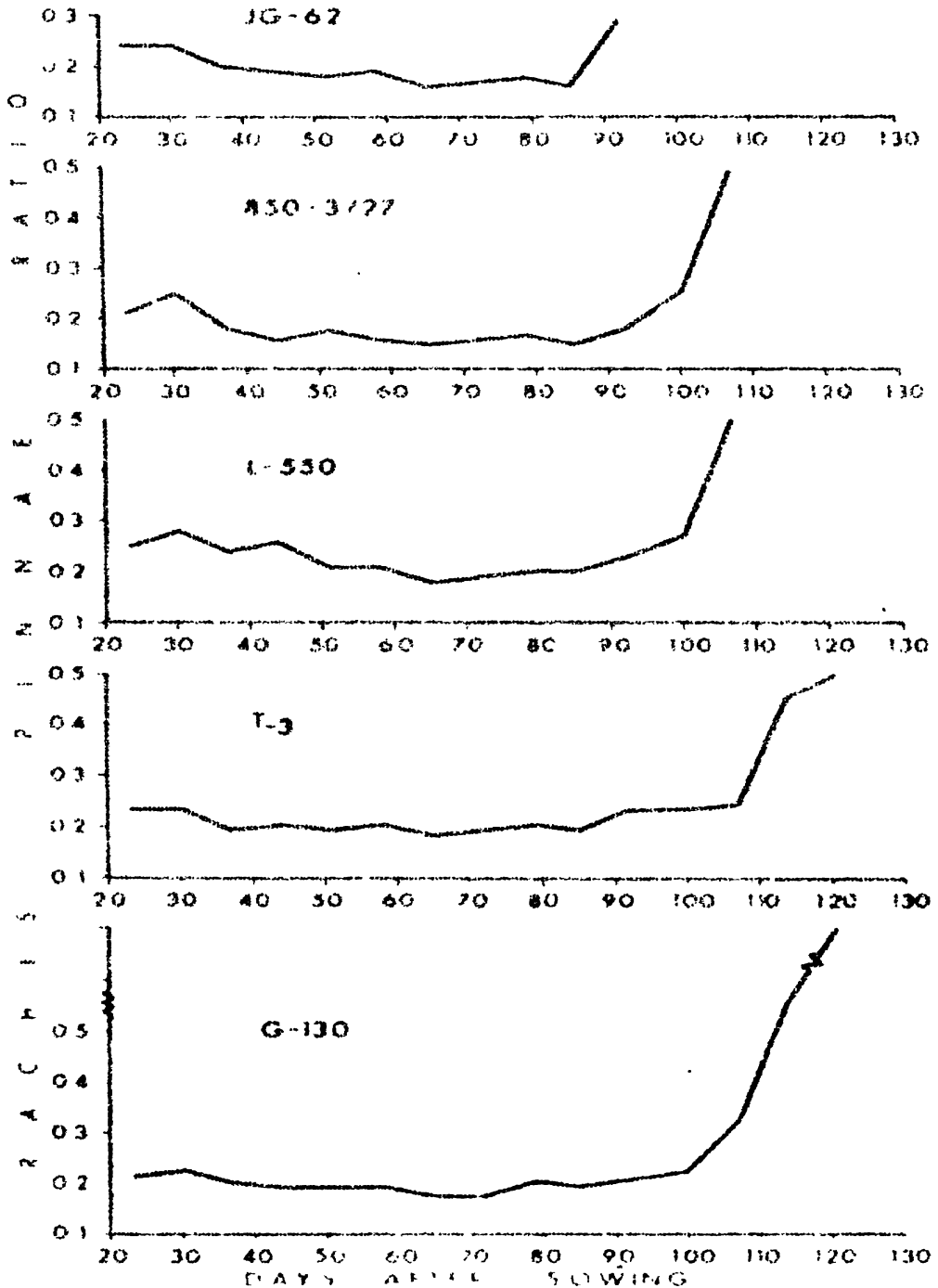
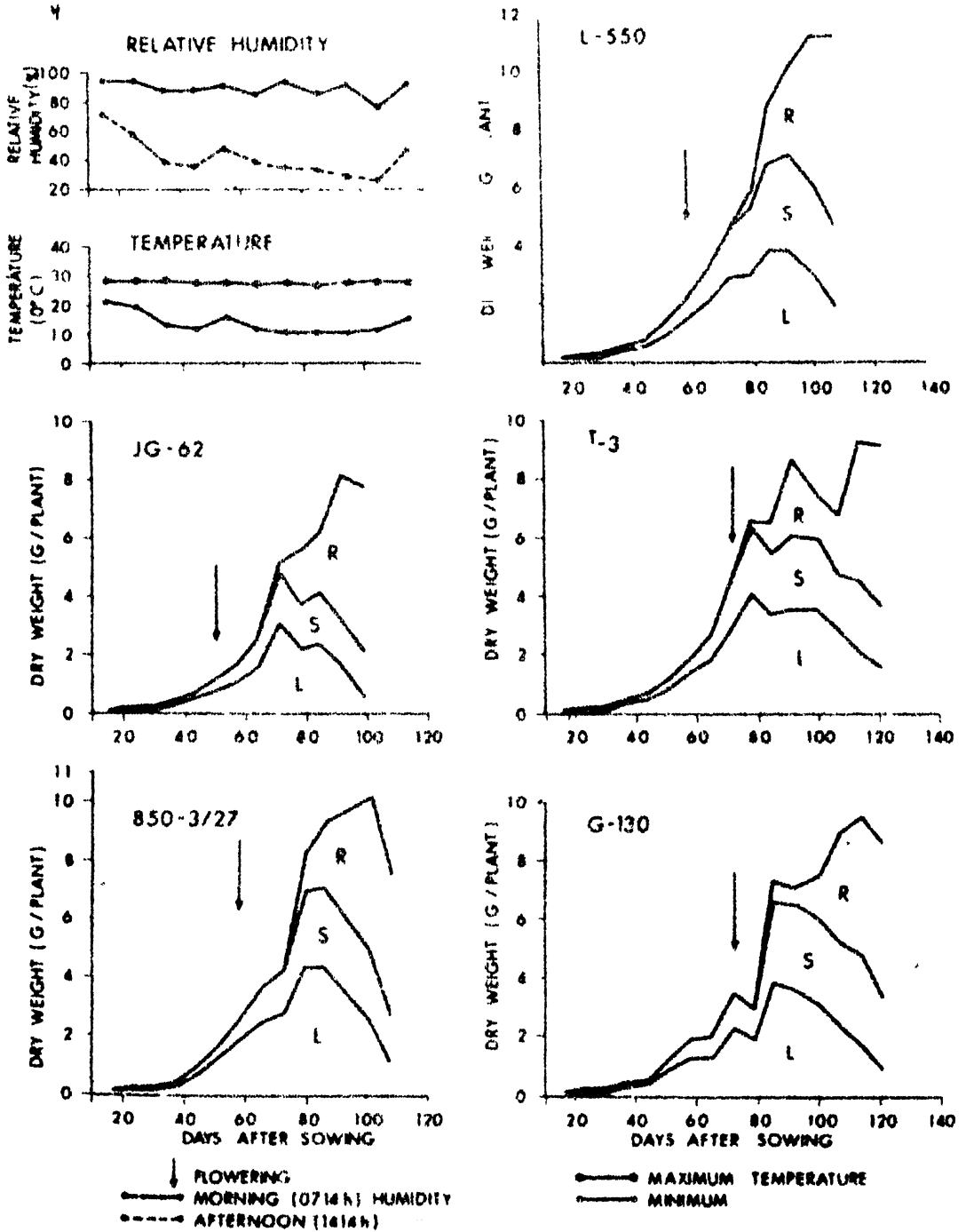




FIGURE 4  
 RATIO OF DRY WEIGHT OF RACHIS  
 AND PINNAE



**FIGURE 5**  
**DRY MATTER IN LEAVES (L) STEMS (S) AND REPRODUCTIVE**  
**STRUCTURES (R)**



The amount of dry matter at the time of flowering was related to the length of the pre-flowering period. The percentage of the total dry weight at the time of harvest which was added after flowering was greatest in the early cultivar JG-62, less in the mid-duration cultivars (850-3/27 and L-550) and least in the late cultivars (T-3 and G-130) (Table 4).

The dry matter production per day was highest in the mid-duration and lowest in the late-duration cultivars (Table 4).

Table 4. Total Dry Weight Per Plant at Different Stages of Growth.

Cultivar	At flowering (g)	At harvest (g)	Dry weight at harvest added after flowering (%)	Pod weight as % of dry weight added after flowering.	Total dry weight added per day throughout crop growth (mg/day)
JG-62	1.201	8.210	85.4	82.2	82.1
850-3/27	2.487	10.180	75.6	62.0	95.1
L-550	2.253	11.250	80.0	72.8	105.1
T-3	5.440	9.340	50.3	100.0	77.2
G-130	3.535	9.500	62.8	90.4	78.5

Leaves

The leaves accounted for most of the dry weight of the plants during the vegetative phase and during the earlier part of the reproductive phase. Thereafter leaf-fall began and the leaves made up a smaller and smaller proportion of the total dry weight (Fig. 5). The pattern of rise and fall in leaf dry weight is very similar to the change with time of LAI (Fig. 2) and leaf number per plant (Fig. 1).

Stems

Roughly a third of total dry weight of the plants was made up by the stems until about the middle of the reproductive phase. In the early and mid-duration cultivars this proportion declined to 18-25% of the total (Table 5). In the early and medium-duration cultivars there was also an absolute decline in stem weight prior to harvest (Table 6).

Table 5. Stem weight as percentage of total dry weight.

Cultivar	Stem weight as % of total dry weight		
	72 days after sowing.	At time of maximum leaf weight.	At time of harvest.
JG-62	37	36	18
850-3/27	34	31	24
L-550	39	34	25
T-3	35	32	27
G-190	35	36	32

Table 6. Decline in stem weight prior to harvest.

Variety	Maximum stem weight.	Stem weight at harvest.	Pod weight at harvest.	Decrease in stem weight Pod weight at harvest.	X 100
JG-62	1.8	1.4	5.7	7.0	
L-550	3.3	2.8	6.6	7.6	
850-3/27	2.6	1.6	4.8	20.8	
G-130	3.1	3.1	5.4	0	
T-3	2.5	2.5	5.4	0	

At the time of harvest there was a considerable difference between cultivars in the relative weights of main stems, primary, secondary and higher-order branches (Table 7).

Table 7. Average dry weights of main stems and branches of different orders at the time of harvest.

Cultivar	Dry weight per plant (g)					Main stem as % of total.
	Main stem	Primary branches	Secondary branches	Tertiary branches	Total	
JG-62	0.80	0.82	0.17	-	1.79	45
BEG-482	0.54	1.27	1.35	0.22	3.39	16
Chaffa	0.74	0.67	0.33	0.03	1.77	42
850-3/27	0.93	1.15	0.37	0.01	2.46	38
L-550	0.84	1.26	0.72	0.09	2.91	29
T-3	0.68	1.57	1.06	0.04	3.35	20
G-130	0.65	1.25	1.17	0.17	3.24	20

The highest percentage contribution of the main stem was found in JG-62 and the lowest in BEG-482. These differences were roughly related to the number of branches per plant (Table 1) but there was no very close agreement between total number of branches, or even number of primary branches, and the relative contribution of branches and main stems to total stem weight; this is because of differences in the average weights of the branches.

### Reproductive Structures

In the early and mid-duration cultivars the reproductive structures flowers plus (i.e. / pods plus pedicels and peduncles) made up a very small proportion of the total dry weight for the first 2-3 weeks after flowering, but in the late cultivars (T-3 and G-130) there was a more rapid growth of the reproductive structures (Fig.5). In all cultivars after about the first three weeks of the reproductive period the majority of the pods had already been formed (Fig. 2). Most of the dry matter in the reproductive structures was accumulated in the latter half of the reproductive period as a result of the growth of the existing pods.

By the time of harvest in all cultivars the pods made up the majority of the weight of the plants.

The proportion of the dry matter accumulated by the plants after flowering which was partitioned into the pods was between 90 and 100% in the late-duration cultivars and 62-82% in the others (Table 4). These figures refer only to the net dry weight of the plants and do not take into account the dry matter lost as a result of leaf-fall; the percentages would be lower if corrected for leaf-fall, but at present we do not have the data necessary for making this correction.

## 2. ANALYSIS OF YIELD

### Results

The highest yield per unit area was given by cvs Chaffa and 850-3/27 (22.9 quintals/ha) and the lowest by G-130 (16.8 quintals/ha) (see Fig. 6).

Data on the yield per plant and its components is given in Table 3 for six cultivars.

The yield per plant varied as Chaffa = 850-3/27 > L-550 > G-130 > BEG-482 > JG-62 > T-3. Highest pod number was produced on BEG-482 and lowest on 850-3/27. The average number of seeds per pod was greatest in Chaffa and BEG-482 (1.3) and least in L-550 and JG-62 (1.0). The ratio of weights of seed to pod walls was the highest for Chaffa and 850-3/27 (5.1 and 4.9 respectively) and lowest for BEG-482 (3.2). Seeds of 850-3/27 were the boldest and of BEG-482 smallest. The average seed size of 850-3/27 was almost three times that of BEG-482. There was a considerable variation in Harvest Index of the seven cultivars which ranged between 53-69%.

In JG-62 (a double-podded cultivar) a greater contribution to total yield was made by nodes bearing single pods than by nodes bearing double pods (Table 9). Of the total number of pod-bearing nodes on a plant only 26% bore double pods. On the main stem the percentage of double-pod bearing nodes was the highest (40.7%) and lowest on the secondary branches (11.0%); none were found on tertiary branches.

Table 8. Yield per plant and yield components of chickpea cultivars.

	C U L T I V A R S						
	JG-62	BEG-482	Chaffa	850-3/27	L-550	T-3	G-130
Yield per plant (gm)	5.78	5.93	6.88	6.86	6.39	5.06	6.0
No. of pods per plant	35.5	43.5	33.6	23.2	30.8	33.1	30.4
No. of seeds per plant	37.2	57.0	42.3	25.6	30.8	38.7	32.5
No. of seeds per pod	1.0	1.3	1.3	1.1	1.0	1.2	1.1
Seed weight pod wall weight	4.2	3.2	5.1	4.9	4.5	4.0	4.0
100 seed weight (gm)	15.6	10.4	16.3	26.8	20.7	13.1	18.6
Harvest Index (%)	66	53	69	64	60	56	53

Table 9. Analysis of the contribution to yield of double- and single-podded nodes in cv JG-62.

	Main stem	Primary branches	Secondary branches	Tertiary branches	Total
Yield (g/plant) from double-podded nodes	0.706	1.445	0.187	-	2.338
Yield (g/plant) from single-podded nodes	0.657	2.027	0.748	0.019	3.451
Double-podded/Node No./plant	2.2	4.5	0.63	-	7.33
Single-podded Node No./plant	3.2	12.2	5.12	0.14	20.66
% double-podded Nodes/plant	40.7	26.9	10.9	-	26.2
No. of seeds per pod: on double-podded nodes	1.02	1.02	1.03	-	1.02
On single-podded nodes	1.20	1.05	0.98	1.0	1.05



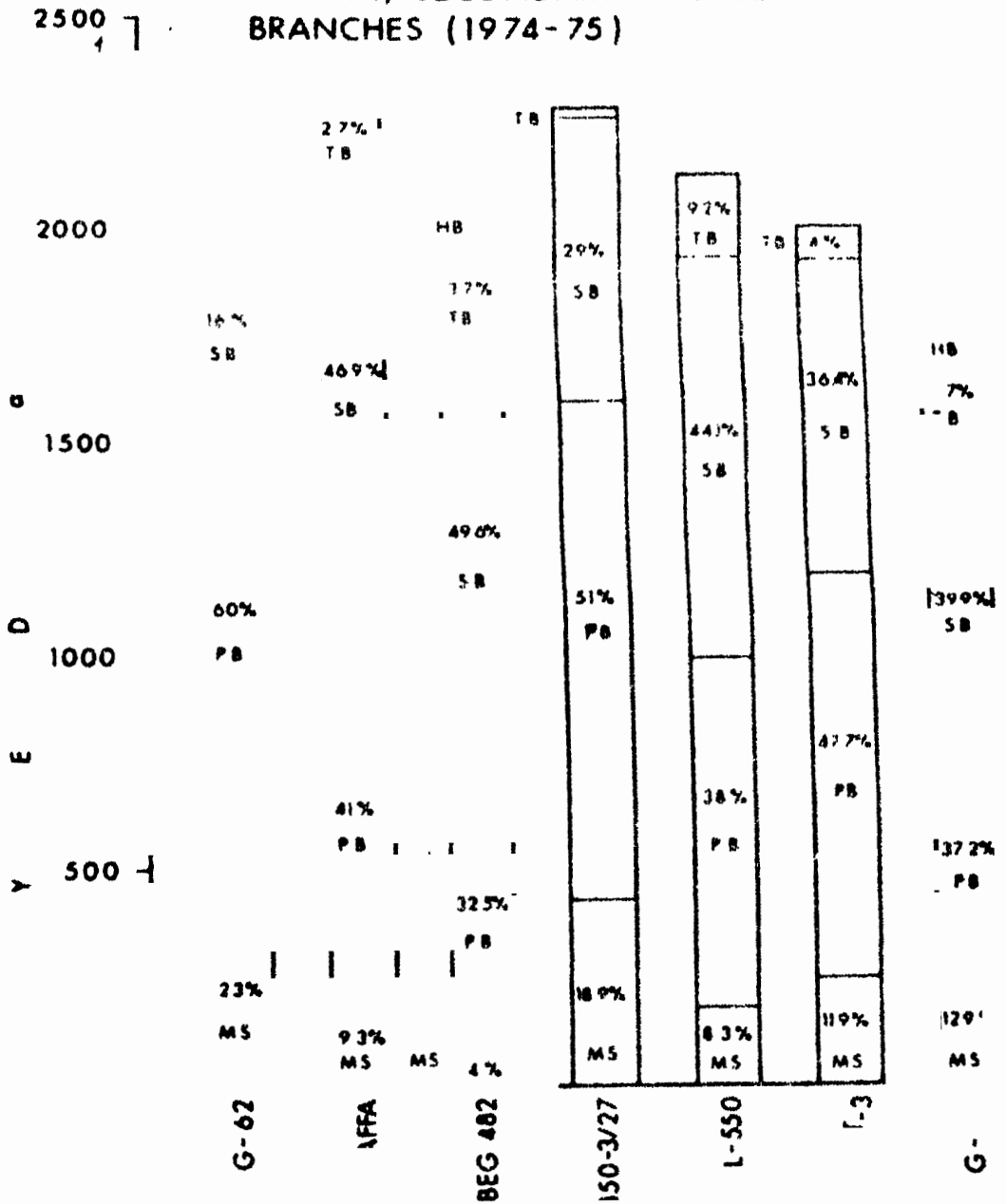
The percentage of double-pod bearing nodes on primary branches was more or less equal to the percentage of double-pod bearing nodes on the whole plant. The number of seeds per pod of single-podded nodes was a little higher than that of the double-podded ones on the main stem, but on an average the number of seeds per pod did not differ between single and double-podded nodes.

The contribution to yield by pods borne on the main stem and on branches of different orders in the same six cultivars is depicted in Fig. 6. In general, most of the contribution to the yield (about 80%) was accounted for by the primary and secondary branches. The main stems of JG-62 and 850-3/27 contributed about 23 and 19% respectively to total yield and in JG-62 the contribution from main stem was higher than that from secondary branches. In BEG-482 main stems contributed very little to the total yield, less than a third of that from the tertiary branches. In L-550 the contribution from main stems and tertiary branches was the same.

The "Harvest Indices" of the main stems and branches were calculated and are shown in Table 10. In general the "Harvest Index" was lowest for the main stem, higher for primary branches and higher still for the secondary and tertiary branches.

A nodewise analysis of yield components was made on the main stems and on the branches of different orders. The nodes were numbered from the lowest (i.e., most proximal) pod-bearing node on the main stem or branches. The data are presented graphically in Fig. 7.

FIGURE 6 VARIETAL DIFFERENCES IN YIELD AND RELATIVE CONTRIBUTION OF MAIN STEM, PRIMARY, SECONDARY AND TERTIARY BRANCHES (1974-75)



MS - MAIN STEM  
 PB - PRIMARY BRANCHES  
 SB - SECONDARY BRANCHES

TB - TERTIARY BRANCHES  
 HB - HIGHER ORDER BRANCHES

FIGURE 7 A CULTIVAR CHAFFA  
 COMPONENTS OF YIELD NODEWISE ON MAIN STEM,  
 PRIMARY, SECONDARY AND TERTIARY BRANCHES

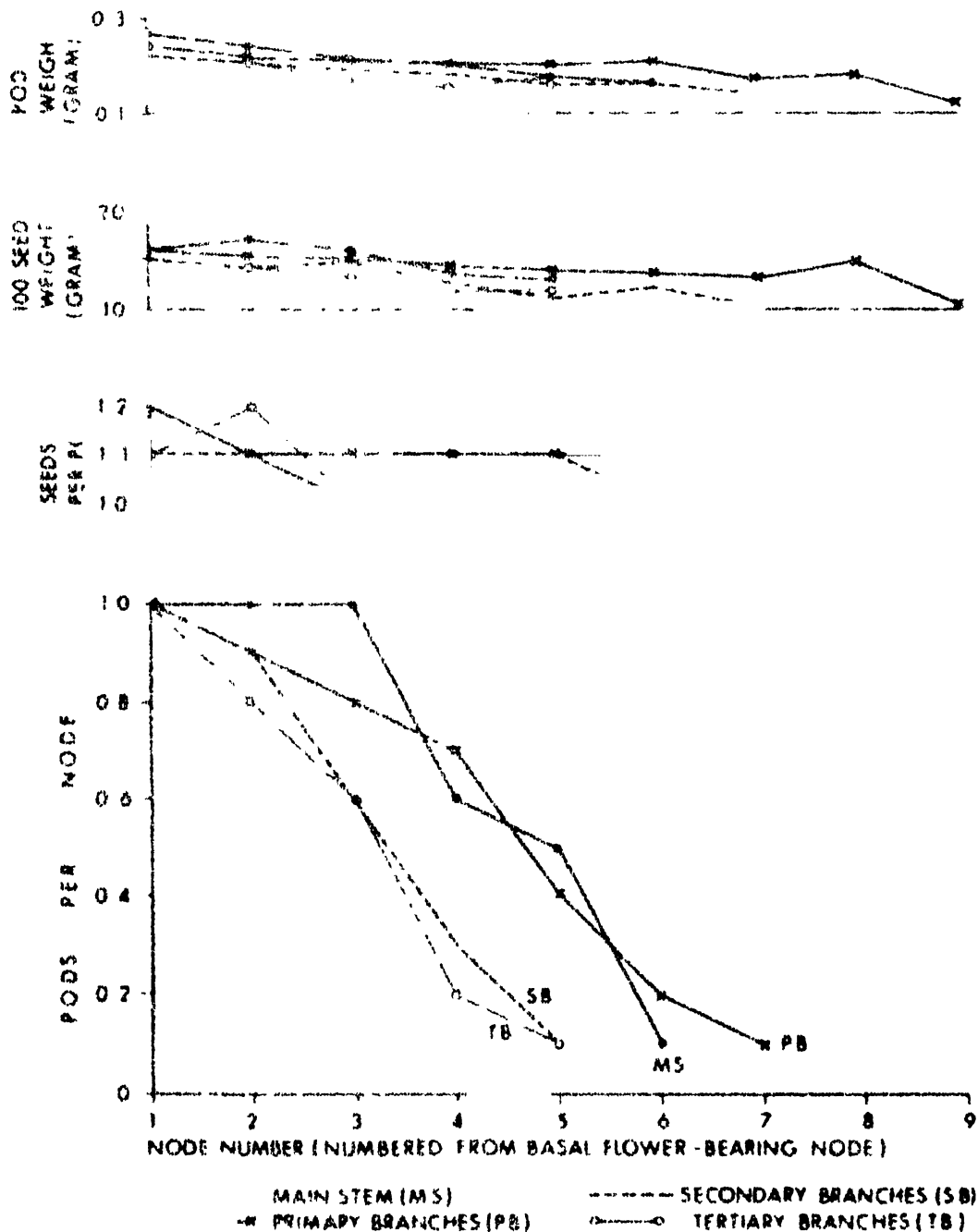


FIGURE 7 B CULTIVAR JG-62

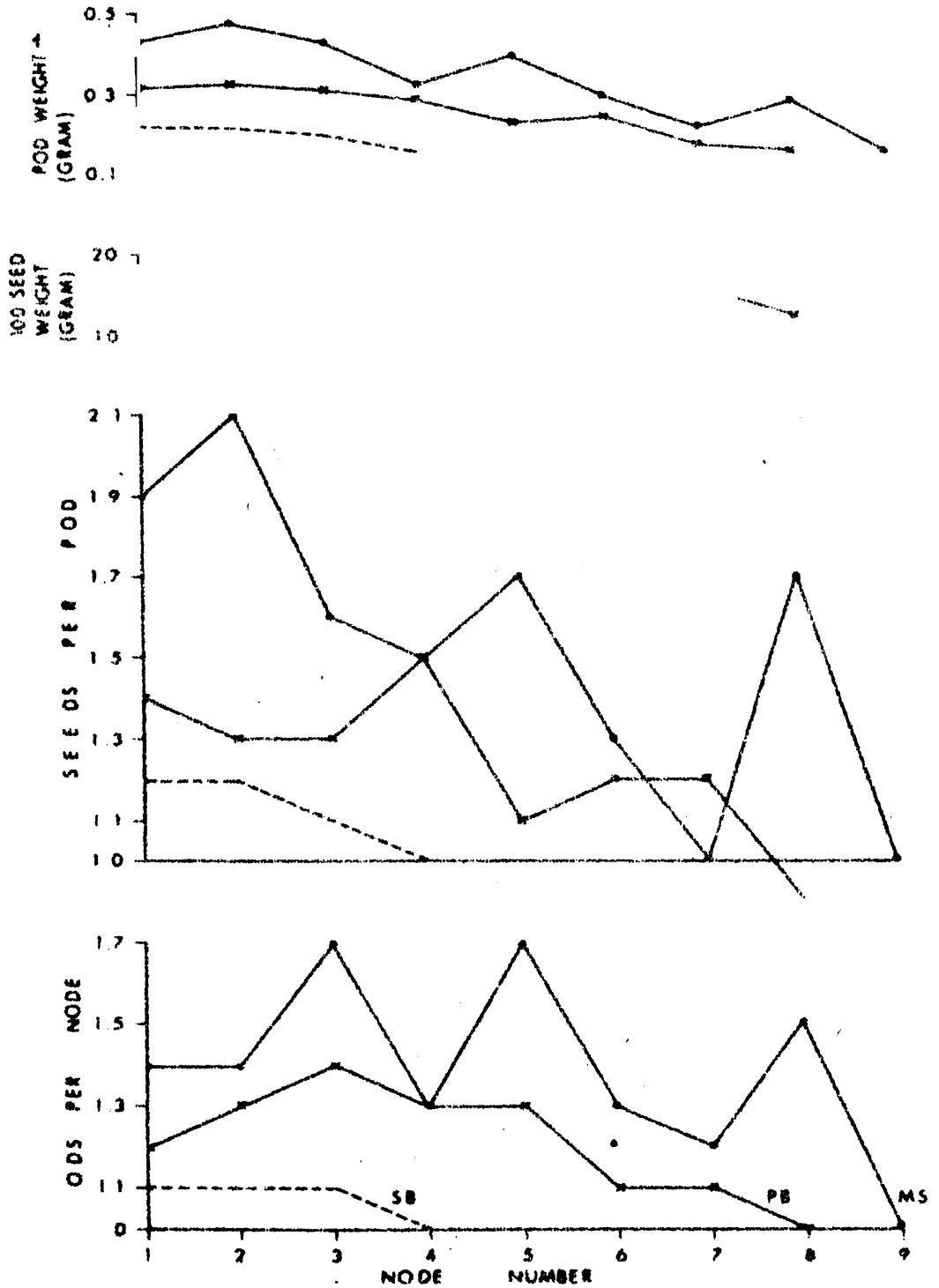


FIGURE 7C CULTIVAR 850-3/27

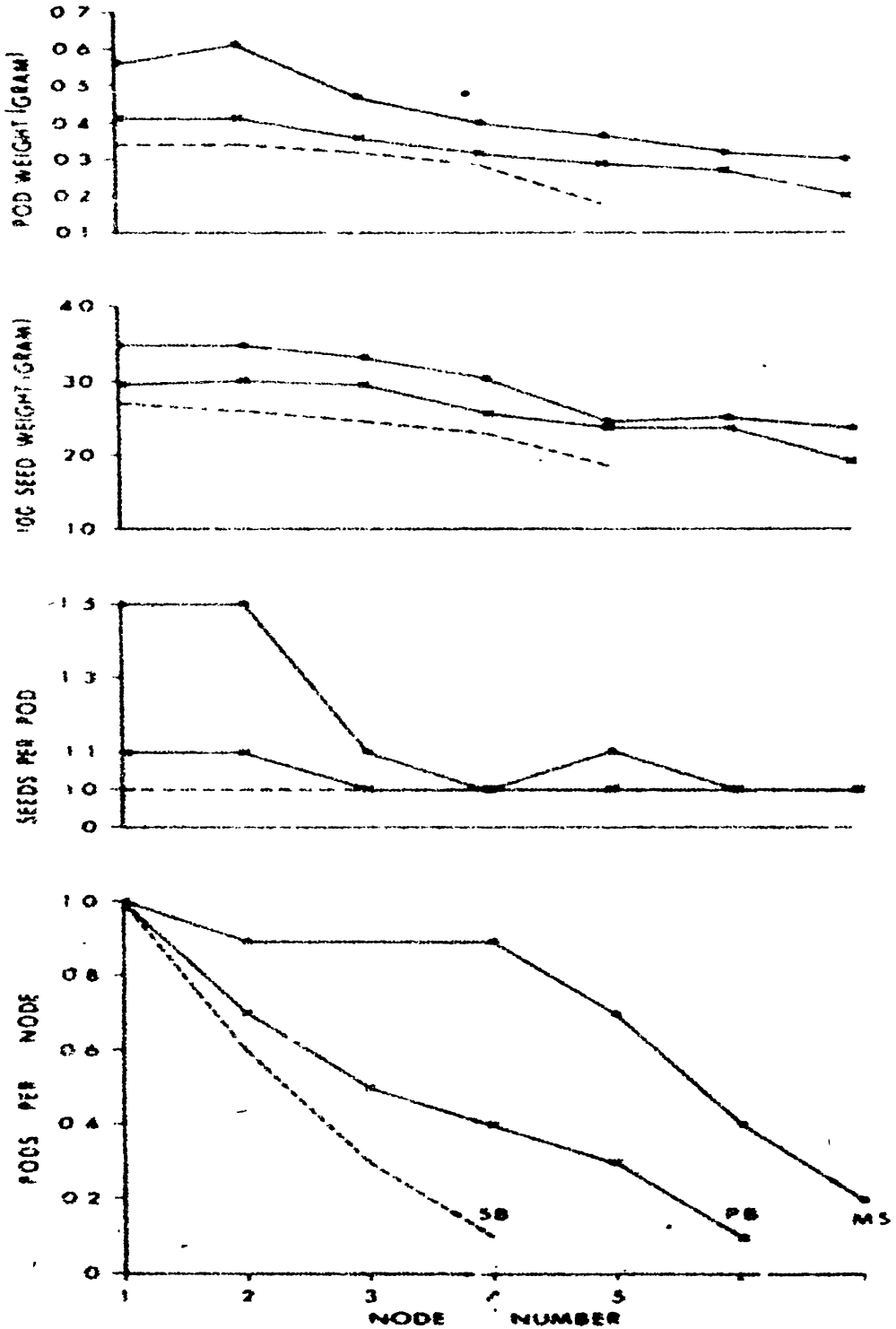


FIGURE 7D CULTIVAR L-550

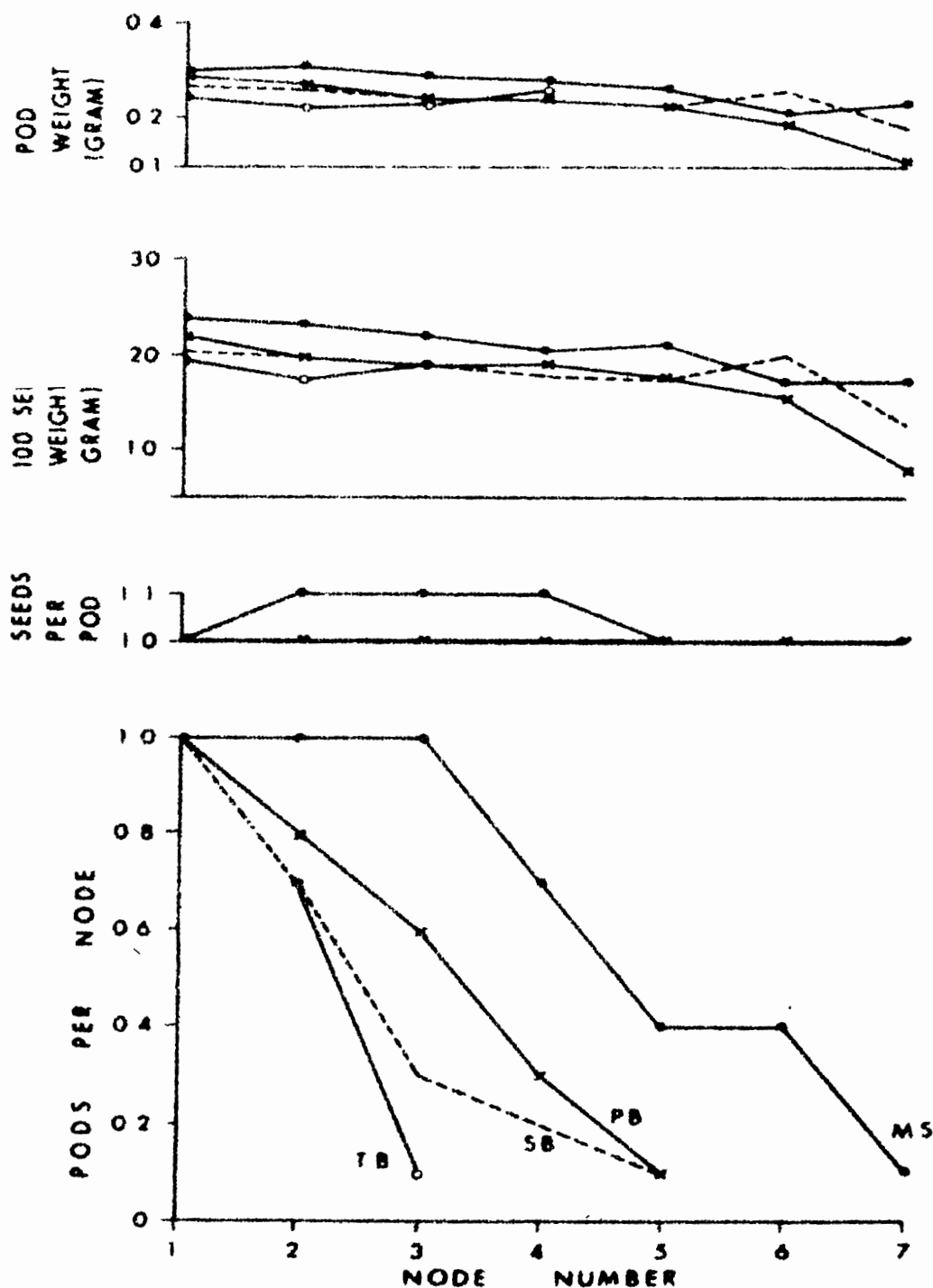


FIGURE 7 E CULTIVAR T<sub>3</sub>

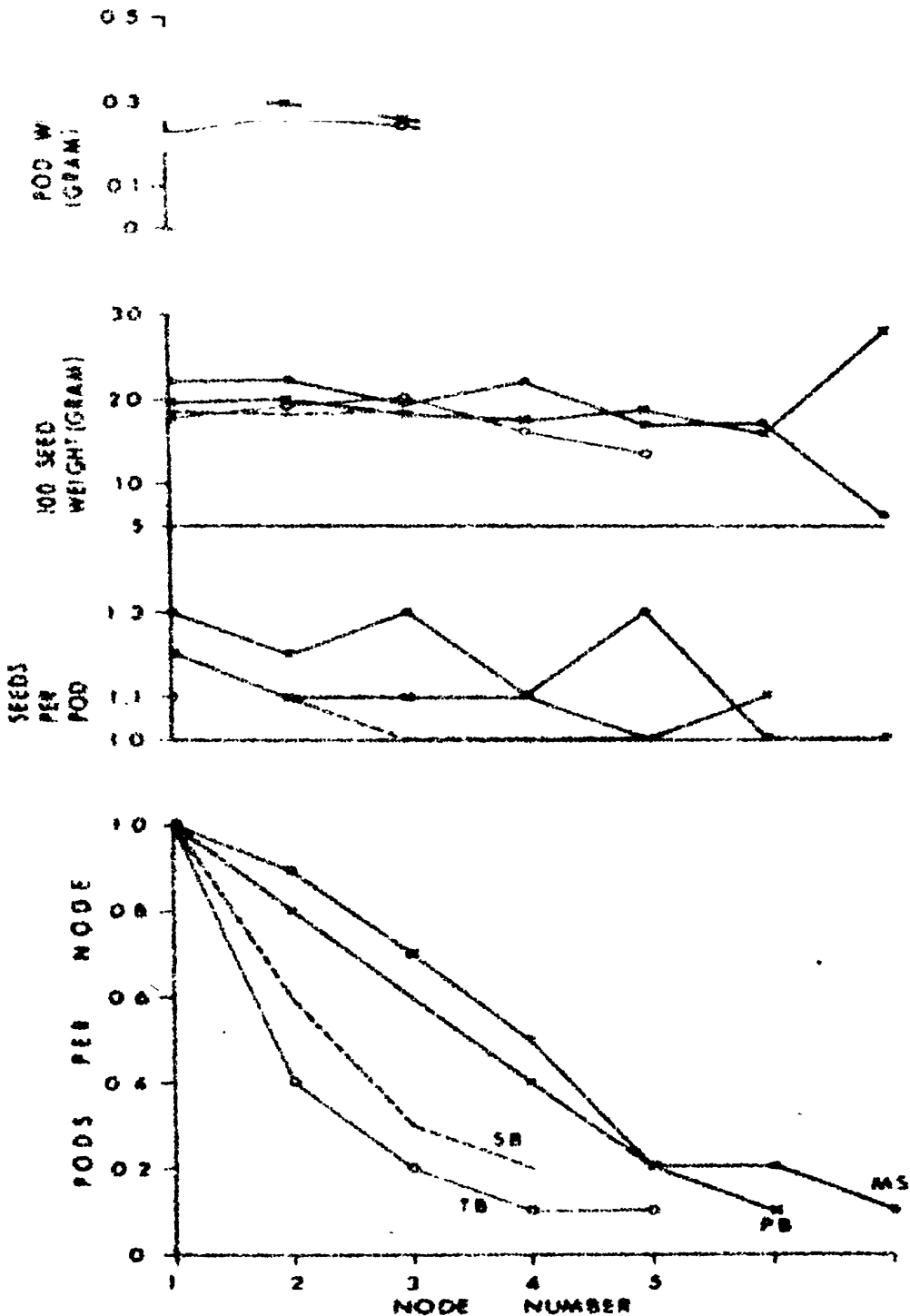
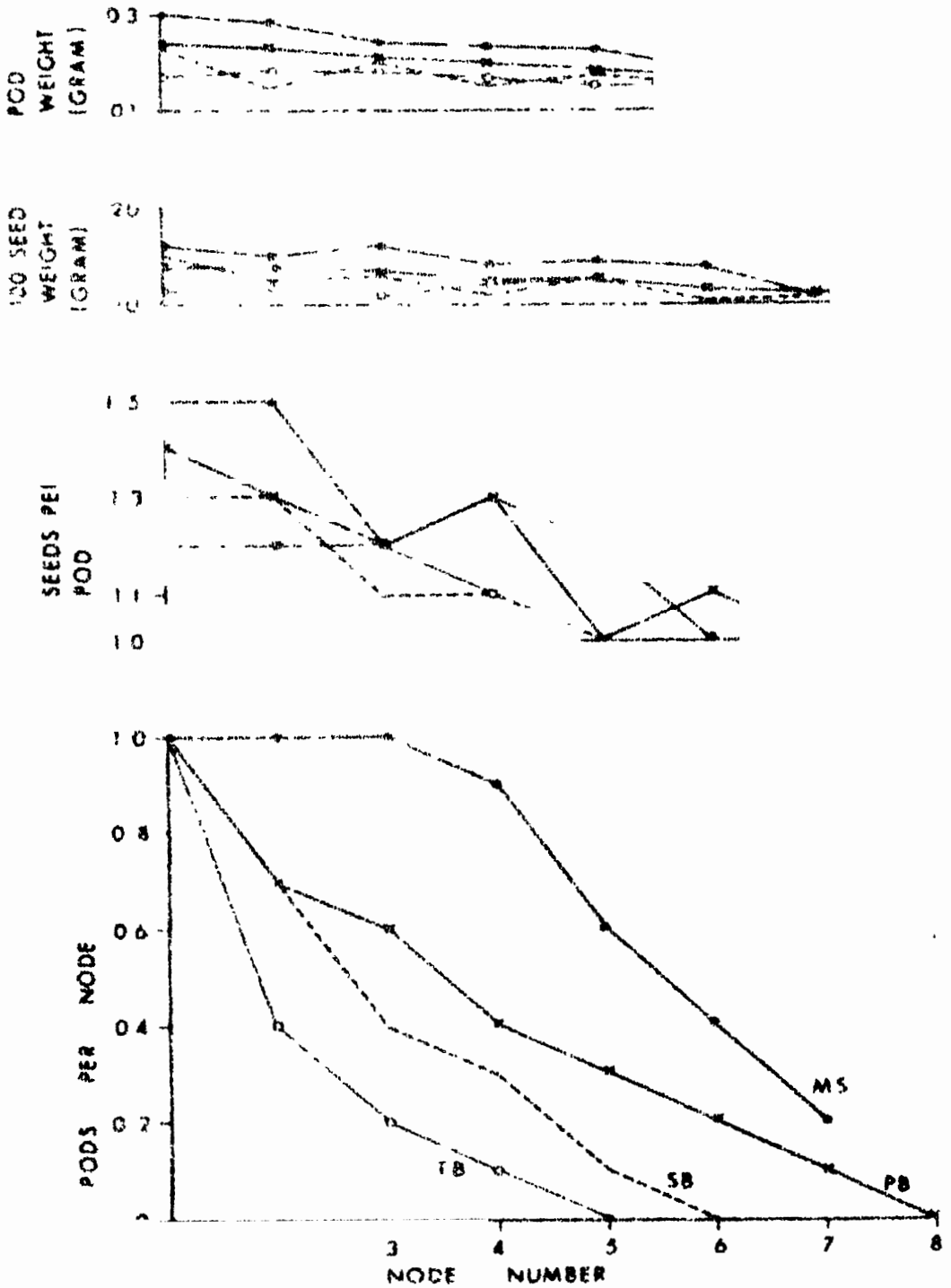


FIGURE 7F CULTIVAR G-130





On the main stems and branches of all orders, all yield components (pod number per node, pod weight, seed weight and seed number per pod) declined acropetally. The same general pattern was found in all cultivars. These results contrast very strikingly with the pattern found in pigeonpeas (see Pigeonpea Physiology Report Figs. 21-23) where all yield components except pod number per node remained constant from lower to upper nodes.

Table 10. "Harvest Index" of main stem and branches of different orders.

Cultivar	"H A R V E S T I N D E X" (%)					Whole plant
	Main stem	Primary branches	Secondary branches	Tertiary branches	Quaternary branches	
JG-62	55	68	71	33	-	66
BEG-482	28	50	57	63	58	53
Chaffa	42	69	58	73	-	69
850-3/27	52	66	72	75	-	64
L-550	36	57	68	75	74	60
T-3	46	56	58	70	-	56
G-130	45	52	55	63	73	53

### 3. NITROGEN UPTAKE AND DISTRIBUTION

#### Results and Discussion

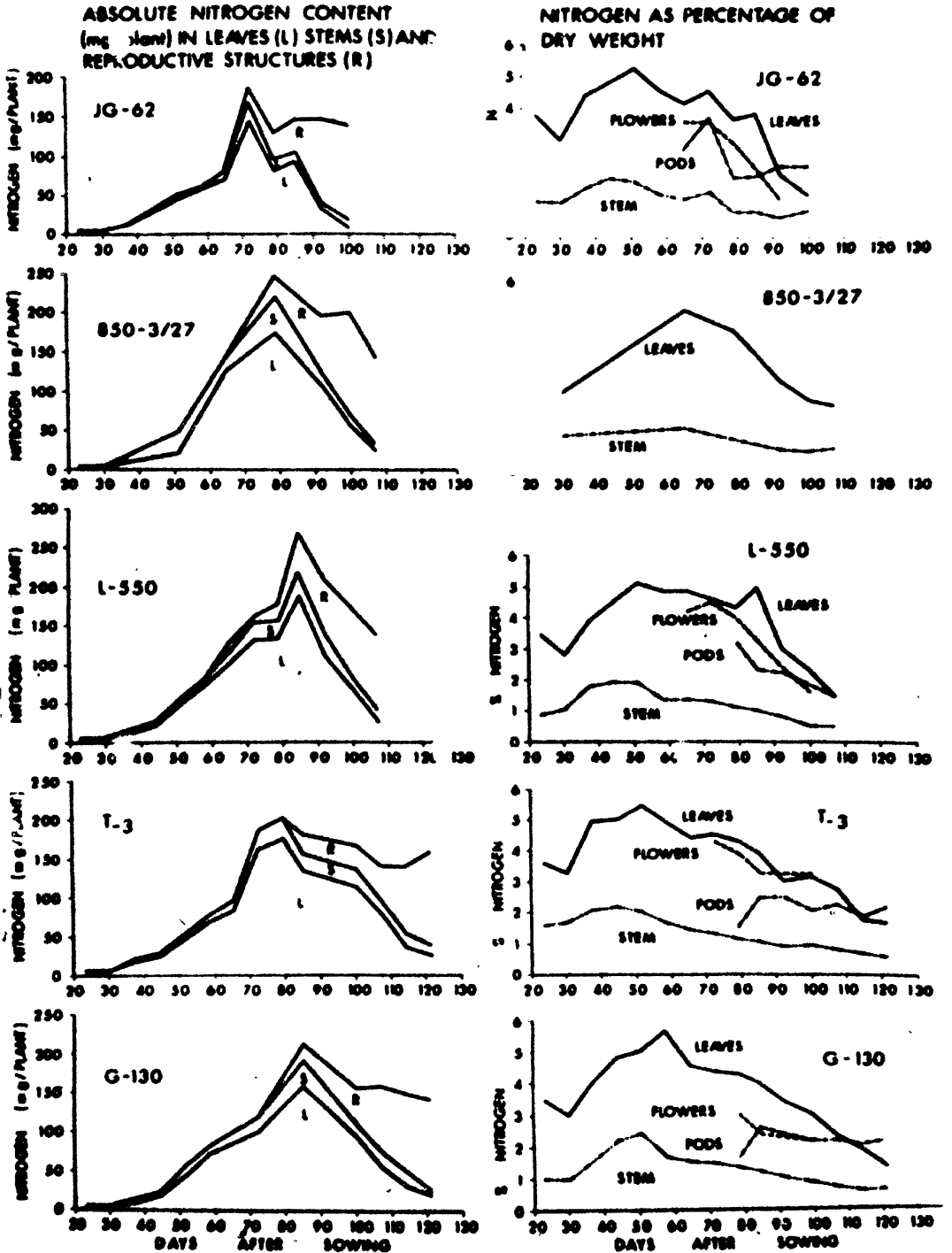
The absolute nitrogen content and the nitrogen content expressed as a percentage of the dry weight of leaves, stems, flowers and pods at different stages of growth of the five cultivars are shown in Fig. 8. The absolute nitrogen content per plant and its distribution between the leaves, stems and reproductive structures was calculated by multiplying the dry weight of these components (which was determined in the growth analysis) by the percentage nitrogen content. The uptake of nitrogen into the plants during the vegetative and early reproductive phases roughly paralleled the pattern of dry matter accumulation (Fig. 5), but thereafter the nitrogen content per plant fell while the dry weight of the plants was still increasing.

In all cultivars the percentage nitrogen content of the leaves increased during the first 40-50 days to over 5% and subsequently declined to less than 2% at the time of harvest. This decline began before the maximum leaf number per plant (Fig. 1) or LAI (Fig. 2) had been reached. The nitrogen content of leaves which had fallen from the plant was in each cultivar more or less the same as the nitrogen percentage in the attached leaves at the time of harvest.

The absolute nitrogen content in the leaves of the plants declined very steeply during the reproductive phase as a result both of the net loss of leaves from plant and of the decline in the nitrogen content of the leaves which remained. During this period the total amount of

**FIGURE 8**

**CHANGE IN NITROGEN CONTENT OF LEAVES, STEMS AND REPRODUCTIVE STRUCTURES WITH TIME**



nitrogen in the plants also declined; most of this decline must have been owing to the loss of nitrogen from the plants in the fallen leaves. Some nitrogen must also have been lost in falling flower petals but compared with the leaves this source of loss would have been very small.

The percentage nitrogen content of the stems followed a similar pattern to that of the leaves, with a rise up to about 40-50 days and then a fall. The fall in nitrogen percentage which took place up to 80-90 days could have been due in part to a "dilution" of the nitrogen by the growth of the stems (see Fig. 5); but subsequently the dry weights of the stems underwent no further increase in cvs T-3 and G-130 and actually declined in the other cultivars (see Table 6). The fall in nitrogen percentage during this period must therefore reflect a translocation of nitrogen out of the stems.

In all cultivars the later-formed flowers contained less nitrogen than the earlier-formed flowers.

The nitrogen percentage of pods after an initial rise showed a decline towards the end of the reproductive phase. The initial rise in the nitrogen percentage of the pods taken as a whole could have been due to the rapid appearance of new pods at this stage (see Fig. 2); such young pods have a nitrogen content considerably higher than that of pods at a later stage of development (see Chapter III). The subsequent decline in the nitrogen content of the whole population of pods probably reflects the decline in nitrogen content which takes place during the course of pod development (Fig. 19).

It is clear from Fig. 8 that while a large gain in the amount of nitrogen in the reproductive structures was taking place, considerable amounts of nitrogen were lost from the leaves and to a lesser extent from the stems. To what extent could this nitrogen have been translocated to the pods?

The nitrogen lost by the leaves and the stems must have been either lost from the plant as a whole, or translocated into other structures. In the case of the stems, the loss in nitrogen must be owing to translocation alone, but nitrogen must have been lost from the leaves both by translocation and by leaf-fall. The only ways in which nitrogen could have been lost from the shoot system as a whole are either by translocation into the roots, or by loss in falling leaves (and to a minor extent in falling flower petals). It seems most unlikely that a net translocation of nitrogen from shoots to roots would have taken place, and therefore the amount of nitrogen lost by the plants as a whole between the time of their maximum nitrogen content and the time of harvest must have been lost in fallen leaves. Therefore if this amount is subtracted from the total amount of nitrogen lost by the leaves as a whole during the same period, the remainder represents the amount of nitrogen translocated out of the leaves into other parts of the plant. This will give an estimate of the maximum amount of translocation from the leaves during the period between the maximum nitrogen content of the plant and harvest; if some nitrogen had continued to be taken up by the plant during this period the net loss from the plant as a whole would be less than the gross loss which took place as a result of leaf fall.

Therefore the calculations outlined above would underestimate the nitrogen loss in leaf fall and consequently overestimate the amount translocated from the leaves. On the other hand, leaf senescence began before the time of maximum nitrogen content per plant (see Fig.11) and some translocation would already have occurred before the period considered in the above calculations; so the total contribution of nitrogen translocation from the leaves would be underestimated by this amount.

With these limitations, and with the assumption that all the nitrogen translocated out of the leaves and stems moved into the reproductive structures (i.e., assuming that there was no net translocation of nitrogen into the roots), the percentage contribution of translocated nitrogen to the total amount of nitrogen accumulated in the reproductive structures at the time of harvest can be calculated. The results of these calculations (Table 11) indicate that the contribution of translocated nitrogen to the nitrogen of the pods was very significant, as high as 96% in cv T-3; even in cv L-550, which had the lowest translocation percentage, half the nitrogen in the pods came from the stems and leaves.

Table 11, Loss, gain and calculated translocation of nitrogen during the reproductive phase.

Cultivar	N lost or gained between time of maximum N content per plant and harvest (mg)					VI	VII
	I	II	III	IV	V	Total N con- tent of repro- ductive structures at harvest (mg)	Percentage of transloca- tion to total N in repro- ductive structures  ( $\frac{V}{VI} \times 100$ )
	Loss from leaves	Loss from whole plant	Calculated translocation from leaves (I - II)	Loss from stem	Total transloca- tion (III + IV)		
JG-62	134	46	88	14	102	119	86
850-3/27	170	104	66	14	80	108	74
L-550	160	128	32	15	47	98	48
T-3	149	48	101	15	116	121	96
G-130	146	72	74	18	92	115	80

#### 4. GENERAL DISCUSSION

The growth analysis was by no means complete because of the omission of measurements of the dry weight of the roots and of the fallen leaves. Especially in the early stages the omission of the roots may introduce considerable errors, and root growth continued in the deeper zones of the soil practically up to the time of harvest (see Chapter II). But the difficulties of a quantitative measurement of the dry weight of the roots, especially in <sup>a</sup>deep-rooted crop such as chickpea, are so great that these measurements were not made. Measurements of the weight-loss in fallen leaves should not present comparable difficulties and such measurements will be made in future work. The loss of a substantial amount of dry weight in the leaves means that after leaf-fall begins all the parameters derived from the growth analysis such as crop growth rate (CGR), relative growth rate (RGR) net assimilation rate (NAR), nitrogen content per plant and harvest index (HI) are distorted. The latter is subject to the maximum distortion and HI uncorrected for leaf-fall may be almost meaningless in chickpeas.

Chickpeas show an indeterminate pattern of growth; vegetative and reproductive growth overlap each other for a considerable time after flowering begins. This is reflected in the continued production of new nodes (Fig. 1), a continued increase in the LAI (Fig. 2) and a continued increase in the dry weights of leaves and stems (Fig. 5) during the earlier part of the reproductive phase. In fact in the early and mid-duration cultivars more dry matter was added to the leaves and stems in the reproductive phase than in the vegetative phase (Fig. 5).

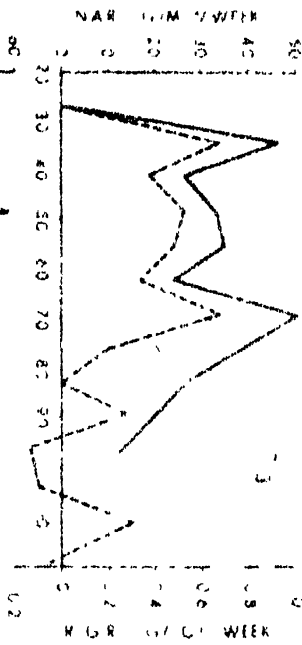
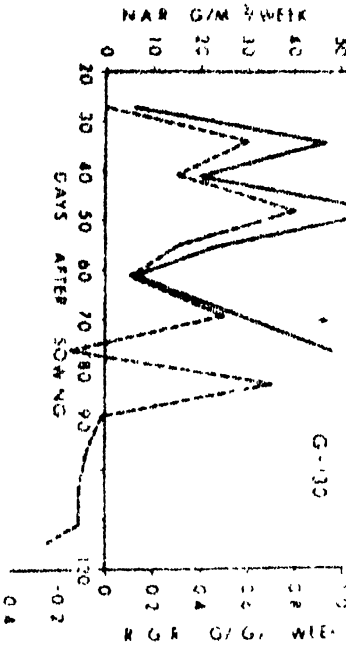
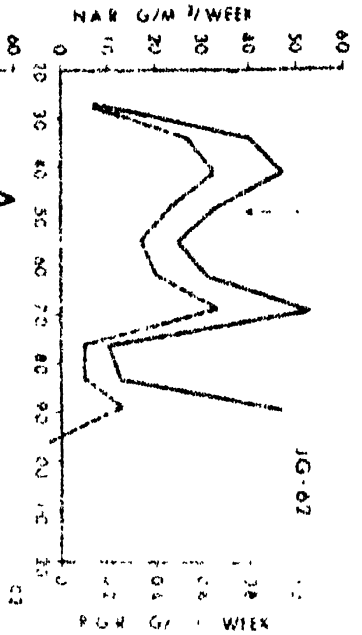
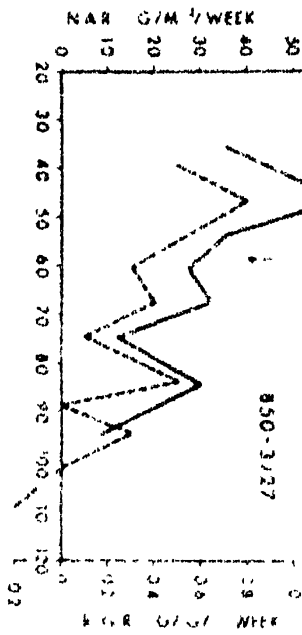
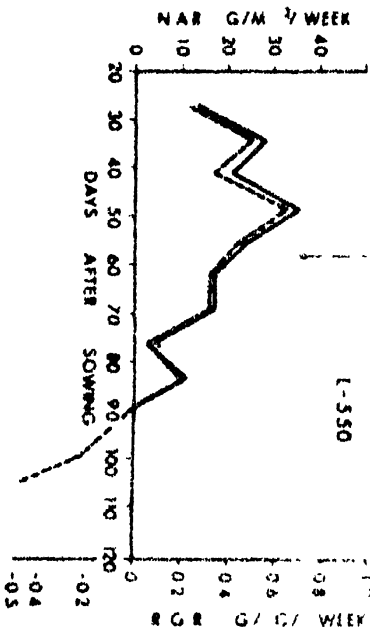


In the early stages the growth proceeded slowly; this is reflected in the low CGR during the vegetative period compared with the CGR soon after flowering (Table 12). In the early and mid-duration cultivars 75-85% of the total dry weight at harvest was added after flowering (Table 4) and if the fallen leaves had been taken into account the proportion would have been still higher.

The NAR ran more or less closely parallel to the RGR in all cultivars (Fig. 9). Both became negative towards the end of the reproductive phase when there was a net loss of dry matter owing to leaf fall; in fact after leaf fall began both RGR or NAR become unreliable and are progressively underestimated.

Although in cvs 850-3/27 and L-550 there was a general decline in both RGR and NAR from the later part of the vegetative phase onwards resembling the pattern found in many other crops, there was no such general tendency in the other cultivars where RGR and NAR fluctuated throughout the growing period. These fluctuations defy interpretation and make a comparison of the NAR of the different cultivars almost impossible.

The slow development of the LAI and the low values of the maximum LAI (2.9) (see Table 2) attained in the different cultivars suggest that competition for light was not a factor limiting growth and yield. The spacing used in these studies (30 x 10 cm) was that recommended for peninsular India. A higher population-density might well have given a higher LAI and a greater interception and utilization of light. In fact we found that an increase in plant population did result in significantly higher yields (see Chapter VI).



— NAR  
 - - - RGR  
 DAYS AFTER SOWING

Table 12. Crop Growth Rate (CGR) during the mid-vegetative phase and a week after the beginning of flowering.

'Cultivar	CGR (g/m <sup>2</sup> /week)	
	During mid-vegetative phase	A week after flowering
JG-62	5.35	22.34
850-3/27	5.44	33.63
L-550	6.14	42.16
T-3	7.40	39.32
G-130	4.64	68.05

The leaf area duration (LAD) varied considerably between the cultivars, but did not seem to show any relation to the total amount of dry matter at the time of harvest (Fig. 10).

Observations of plants grown at different row-spacings suggested that the major factor involved in plant to plant competition was not competition for light, but below-ground competition for water and/or for nutrients. The chickpea crop grows on residual moisture in the soil which recedes continuously during the growth of the crop and thus the ability of the plants to sustain the continued growth and activity of the roots may be the major factor determining the growth and development of the shoot system (see Chapter II).

As the reproductive period proceeded the demand for assimilates by the developing pods continuously increased (see Figs. 5, 21 and 22); at the same time the LAI was decreasing owing to leaf senescence (Fig. 2). Even before the LAI began to decrease the nitrogen content of the leaves started to decline (Fig. 8). A close relationship has been observed in many crops between the leaf nitrogen content and photosynthetic efficiency; if this relationship holds in chickpea, during the reproductive period as well as the fall in leaf area, the photosynthetic efficiency of the remaining leaves would also have been falling. At the same time the nodules were regressing (see Chapter II) and there may well have been a shortage of nitrogen for the development of new tissues : this is suggested by the decline in the nitrogen content of the later-formed flowers (Fig. 8).

This 'vicious circle' of declining availability of photo-  
to  
assimilates and of nitrogen seems likely to have led to a decline in the rate of growth and activity of the roots at a time when the growth and activity of the roots would be even more necessary to extract the receding moisture from the soil; the consequent water stress imposed on the shoot system would further exacerbate this vicious circle of decline and senescence.

In these circumstances it is relatively easy to see how under a given set of climatic conditions, the choice of a cultivar of the right duration is essential for obtaining maximum yields. A cultivar of too short a duration would go into this cycle of senescence and maturation when the availability of water in the soil and favourable

temperatures would have permitted a longer period of growth and hence higher yields to have been obtained. A cultivar of too long a duration would be subject to an increasing stress during the reproductive period owing to a combination of falling atmospheric humidity (and thus increased water loss by transpiration) and declining soil moisture. Rising temperature would impose a further stress, but in fact during the growth period of the cultivars that we studied, the average maximum temperature showed little change and the average minimum temperatures began to rise only towards the end of the reproductive phase of the late-duration cultivars. But the cycle of senescence in these cultivars had already set in before the temperatures began to rise. The date on which LAI began to decline was similar in mid- and late-duration cultivars, which means that in the latter the whole cycle of senescence began near the beginning rather than around the middle of the reproductive phase (see Fig. 2); this may have restricted its duration and have limited the yield. The same conclusion is suggested by a comparison of the onset and progress of leaf senescence in the cultivars of different duration in relation to the time of flowering (Fig. 11).

Although the growth of the late-duration cultivars may have been cut short by the stresses discussed above, this curtailment in itself cannot explain the lower yields of the late than of the mid-duration cultivars (Fig. 6). The reproductive periods of all five cultivars were in fact almost the same (Table 13), and so the limitation to the yield of the late cultivars may have been largely owing to the onset of the cycle of stress and senescence at an earlier physiological stage.

FIGURE 10  
LEAF AREA DURATION (LAD) AND  
TOTAL DRY WEIGHT AT HARVEST

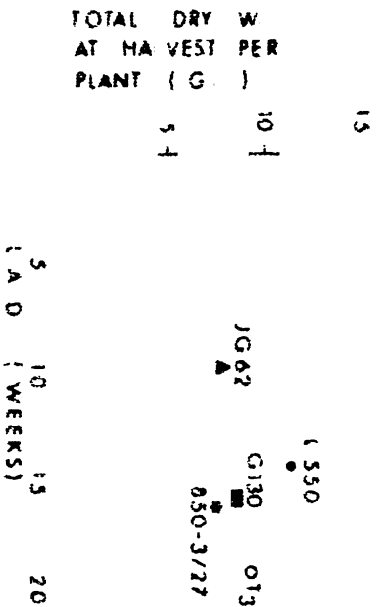
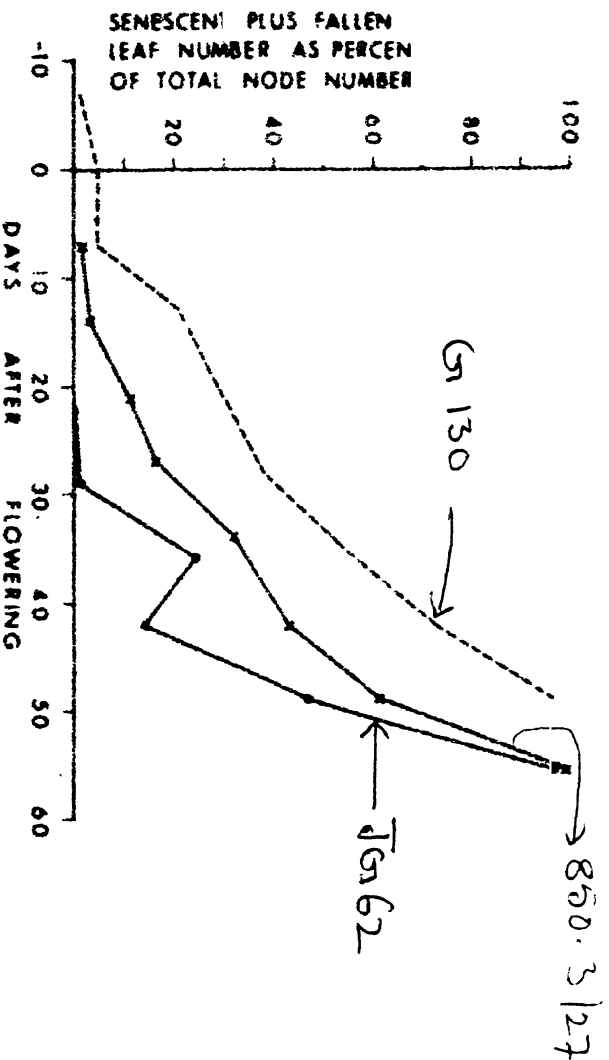


FIGURE 11  
TIME COURSE OF LEAF SENESCENCE



However, in Northern India, which is the main chickpea growing area, the growing season is considerably longer and under those more favourable conditions higher yields are obtained than in Peninsular India, and in general the highest yields are obtained from the late-duration cultivars.

Table 13. Duration of vegetative and reproductive phases.

Cultivar	Date of flowering	Days to flowering	Days to harvest	Duration of reproductive phase (days)
JG-62	20-11-74	51	100	49
850-3/27	27-11-74	58	107	49
L-550	27-11-74	58	107	49
T-3	11-12-74	72	121	49
G-130	11-12-74	72	121	49

## CHAPTER II

### The Development of Roots and Nodules

#### Introduction

The purpose of these investigations was to obtain basic descriptive data on the growth and development of the nodules and of the root system.

#### Methods

Regular observations were carried out on two cultivars, JG-62 and T-3, growing in the experimental plots in black soil (ST-1 area).

The roots were sampled by a mechanical soil auger (tube diameter 7.6 cm). The cores were centred on the stumps of plants which were cut off immediately before hand. Three replicates were taken on each occasion; nearby, cores were taken with a smaller auger (tube diameter 1 cm) for soil moisture determinations (two replicates).

The cores were divided at 15 cm intervals, representing 15 cm increments in depth. Soil moisture determinations were made gravimetrically and represent the percentage loss in weight after oven-drying. For root and nodule counts the soil samples were soaked in water overnight and then washed thoroughly in running water in a sieve. The numbers and lengths of the root fragments and numbers and sizes of the nodules were recorded. The root and nodule samples were dried in an oven at 80°C to constant dry weight for dry weight determinations.



With the exception of the observations on nodules and dry weight determinations, these operations were carried out by the Farming Systems group under the supervision of Dr. Sardar Singh.

### 1. Roots

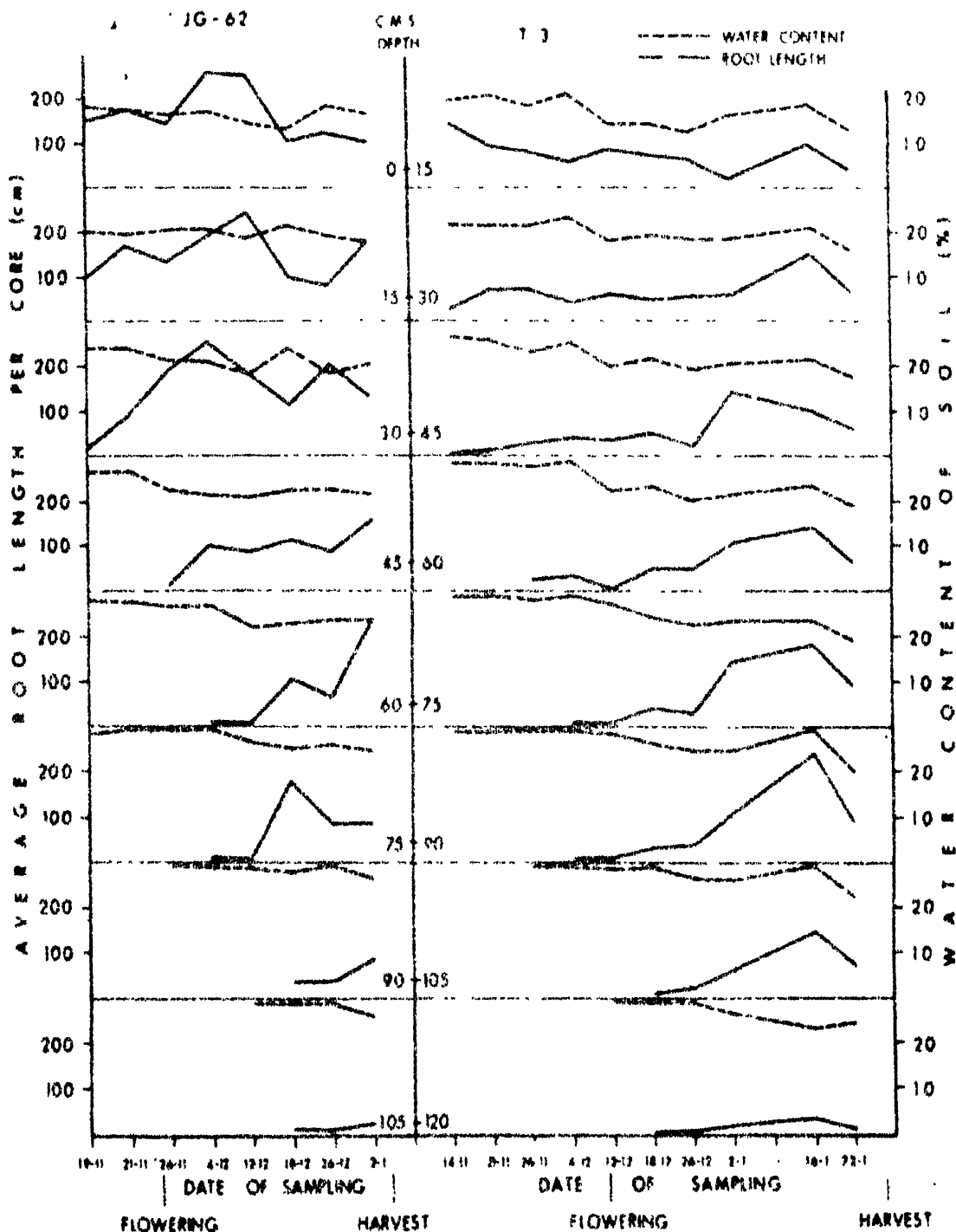
#### Results and Discussion

There was a good correlation between root lengths and root numbers in the various samples. However, root lengths are of more interest from a physiological point of view and are probably a more reliable quantitative measure than root numbers, which are affected by differential damage to the roots during extraction and washing. Only root length data are presented here. Almost no relationship was found between root lengths and root dry weights, probably because the latter are subject to very high errors owing to the adherence of soil particles to the roots even after thorough washing. In future experiments the measurement of root dry weights can be eliminated.

Weekly measurements commenced on 14-11-1974, 45 days after sowing. Results for the two cultivars are shown in Fig. 12. Apart from two very small showers on Nov. 20th and 23rd (1.2 and 3.3 mm rainfall respectively), no rain fell during the period covered by these results.

After 12-12-74 the water content of the soil in the first 15 cms was near or below permanent wilting point (15%) and little or no further root development took place in this surface zone thereafter. However, considerable root development took place in the deeper zones and continued during the reproductive phase of the plants. In both

FIGURE 12  
 ROOT LENGTHS AND MOISTURE PERCENTAGE AT DIFFERENT DEPTHS



cultivars towards the end of the reproductive phase more than half the roots lay in the region below 45 cm; in T-3 half lay below 60 cms (Fig. 13).

The water content of the soil in the lower zones fell as root development took place but remained well above permanent wilting point at the time of maturity.

The post-harvest moisture distribution (on 25-2-1975) in plots on which these different cultivars (JG-62, T-3 and G-130) had been growing is shown in Fig. 14. All cultivars were sown on the same date. More water had been extracted from the soil by the long-duration (T-3, G-130) than by the short-duration (JG-62) cultivars.

The pattern of water depletion within and outside a plot was examined by taking core samples in the rows, between the rows and at 30 cm intervals outside the plot, up to a distance of 120 cms. The samples were taken on 8-1-1975 as the plants inside the plot were reaching maturity; while those in the border rows were still green. Results are shown in Fig. 15. Outside the plot there was little difference in the water content of the soil down to 30 cm, but in the 60-120 cm zone water depletion within the plot owing to the activity of the roots is apparent. Below 90 cms the moisture content of the soil was near field capacity (32%).

From the plants of cultivars Chaffa and T-3 flowers were removed either continuously from the beginning of flowering, or for the first

# FIG. 13 ROOTS - PERCENTAGE AT DIFFERENT DEPTHS

VARIETY T-3 (GROWN IN BLACK SOIL - DATE OF GERMINATION OCTOBER 6, 1974)

TOTAL ROOT  
LENGTH PER

CORE (cm) → 1.9 ——— 4.06 ——— 5.64 ——— 9.84

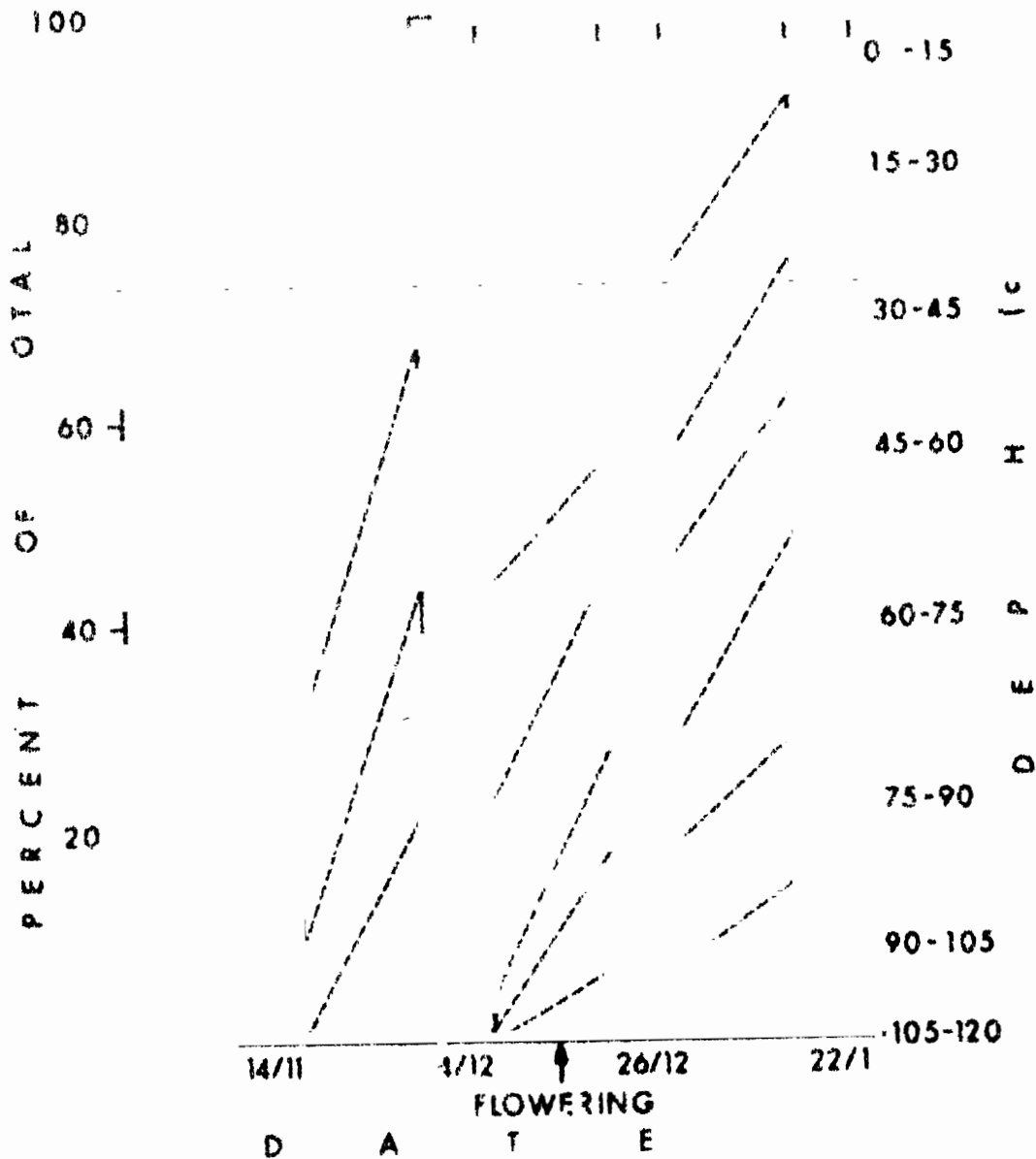
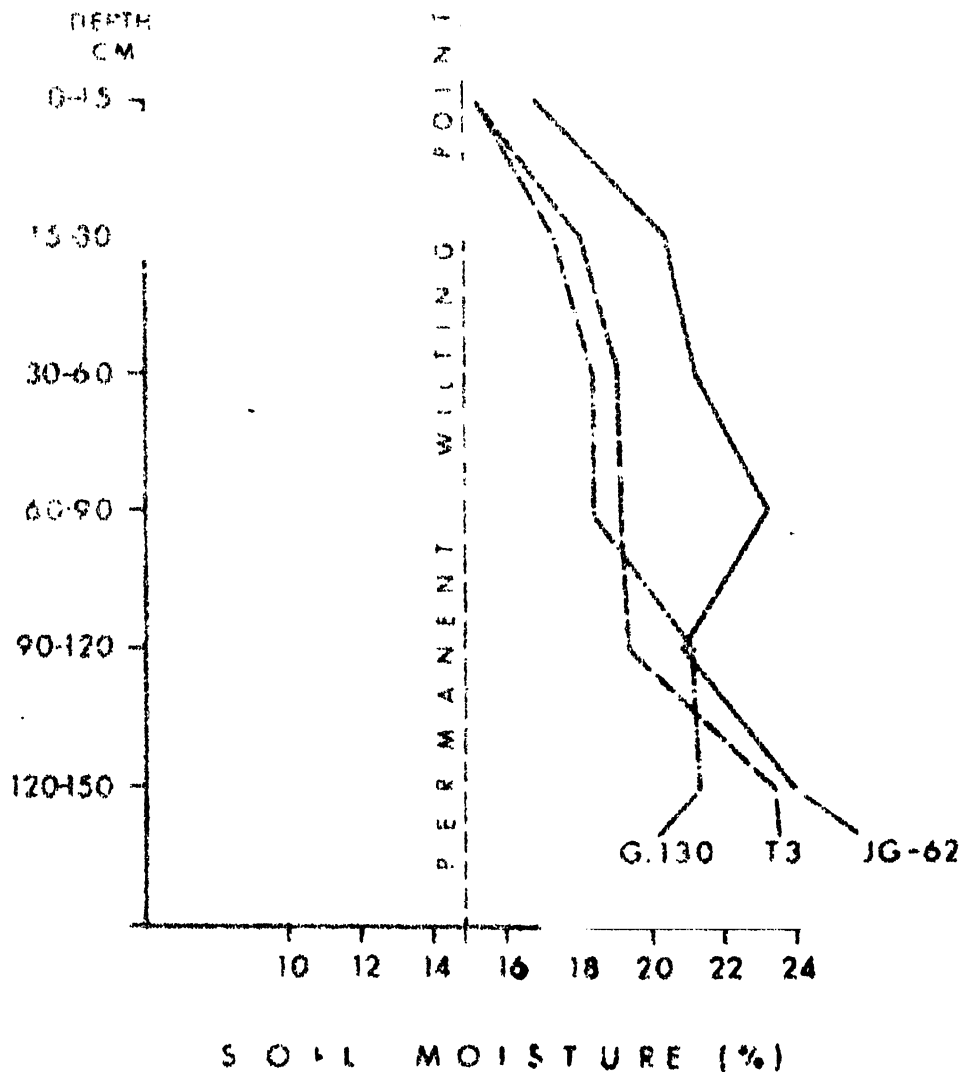


FIGURE 14

WATER PERCENTAGE OF SOIL AT DIFFERENT DEPTHS ON 25-2-75 AFTER HARVEST OF THREE CHICKPEA CULTIVARS (MEANS FROM TWO REPLICATE PLOTS; THREE SOIL CORES PER REPLICATE)





three weeks after flowering, after which pods were allowed to develop. The effect of these treatments on root growth was compared with controls in which normal pod development was taking place. Samples were taken on two dates towards the end of the reproductive period. Compared with controls, more roots were found on the plants where pod development had been prevented or delayed, especially in the deeper zones (below 75 cms) These plants from which flowers had been removed also showed more vegetative growth than controls and remained green after controls had dried up and matured.

Most of the root systems of crops grown under conditions of intermittent rain or irrigation is confined to the surface zones of the soil. By contrast, in the rabi season, when chickpeas are grown, there is a progressive drying-up of the residual moisture in the soil and less and less root-growth and activity can take place in the surface zones. This progressive depletion of the soil moisture from the surface zones downwards and the progressive development of the roots deeper down in the soil are clearly shown by the results presented in Fig. 12. Towards the end of the rabi season, when the surface layers of the soil contain little or no available water, the majority of the chickpea roots lie below 45 cms. This raises a number of interesting questions relating to nutrient uptake. If the surface roots cease to develop and presumably also cease to function in water uptake as the surface soil dries out, it seems likely that most of the nutrients, like most of the water, may be taken up from the deeper zones of the soil. Nutrients in the surface layers of the soil may not be taken up after this soil dries

and root development in this region slows down or ceases. Fertilizer application at the beginning of the rabi season may therefore be of limited efficacy (see Chapter V).

The pattern of root development may well be changed if the surface zones of the soil do not undergo a progressive depletion of moisture as the crop develops, either as a result of rain fall or irrigation. Such a change in pattern of root development might be expected to affect the pattern of nutrient extraction from the soil.

The continued development of the root system during the reproductive phase probably depends in part on the extent of the competition for photo-assimilates by the developing pods. As the plants proceed through the reproductive phase the number of pods increases, the demand for photo-assimilates by the pods increases, while the leaf area (and hence photo-assimilate production) declines (see Chapter I). Therefore the photo-assimilates available for root growth and root activity might be expected to decrease. However, continued root development is necessary for the exploitation of receding and ever-declining amounts of soil moisture. Hence a decline in the development and activity of the roots could have been a major factor determining the drying up, maturation and death of the plants. This conclusion is supported by the following observations:

(i) The delaying or prevention of pod formation allowed more root development to take place and prolonged the life of the plants.

(ii) The early cv JG-62 did not dry up and mature because it had



exhausted the soil moisture (Figs. 12 and 14). It probably matured earlier because pod development took place earlier than in the other varieties.

Thus the limiting factor for the continued growth and development of the plants does not seem to be the amount of water in the soil so much as the ability of the plant to exploit it by the continued development and activity of its root system. On the other hand if more water were available, less root development and activity might be necessary to exploit it. This could be one of the reasons for the fact that plants in border rows remain green and alive after the other plants have dried up and died. Roots of plants in border rows probably have access to more available soil moisture than roots inside the plot (Fig. 15).

## 2. NODULES

### Results

The nodules were almost all confined to the first 15 cm zone of the soil. In most cases 99-100% were found in this region. Occasionally significant numbers of nodules were found in the 15-30 cm zone, but even so these amounted to less than 10% of the total. Therefore, in future work it might be safe to assume that the great majority of the nodules will be recovered by digging out the top 15 cm of the root system.

The nodules continued to grow, branching dichotomously as they did so and tended to form a mass of tissue encrusting the roots. Nodule numbers were recorded, as were nodule sizes, estimated by eye, but these

did not give such a good quantitative measure of nodule development as the dry weight of the nodule tissue.

The weights of nodules of cvs JG-62 and T-3 at different times are shown in Fig. 16. T-3 always had more nodule tissue than JG-62 but both varieties showed a similar pattern of increase and decline.

The delay or prevention of pod setting by the removal of flowers not only prevented the decline of the nodules but resulted in an increase in the amount of nodule tissue over the maximum amount produced in control plants. However, even in plants from which flowers were removed continuously senescence set in eventually and the nodules degenerated. Data for cv T-3 are shown in Fig. 17.

#### Discussion

Although the rise and fall in the mass of the nodules in cvs JG-62 and T-3 were synchronous, the stages of development of the two cultivars was not (Fig. 5). In JG-62 the maximum nodule weight was achieved about 10 days after full flowering, but in T-3 it was achieved about 7 days before full flowering. These results may simply reflect experimental error, but if they can be confirmed they might suggest that environmental factors were influencing the decline of the nodules more than the physiological state of the plants. However, the latter also has a marked effect as revealed by the effects of flower removal (Fig. 17). This is presumably a result of the prevention or reduction of competition for photo-assimilates by developing pods. But even when flowers are removed continuously, the cessation of vegetative growth and the senescence of the plants could not be prevented indefinitely, but took place as the temperatures, particularly the night temperatures, increased.

FIGURE 16

NODULE WEIGHTS AT DIFFERENT TIMES ON PLANTS OF CVS G 62-404 AND T-3

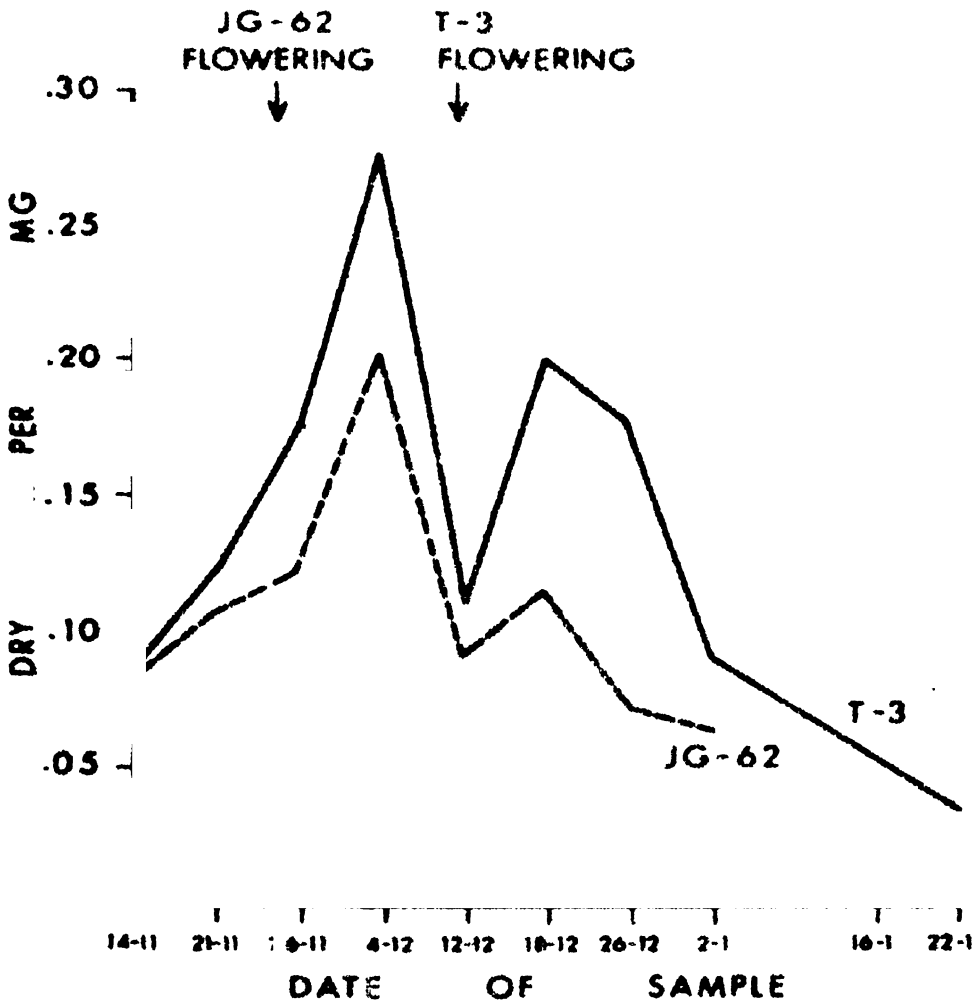
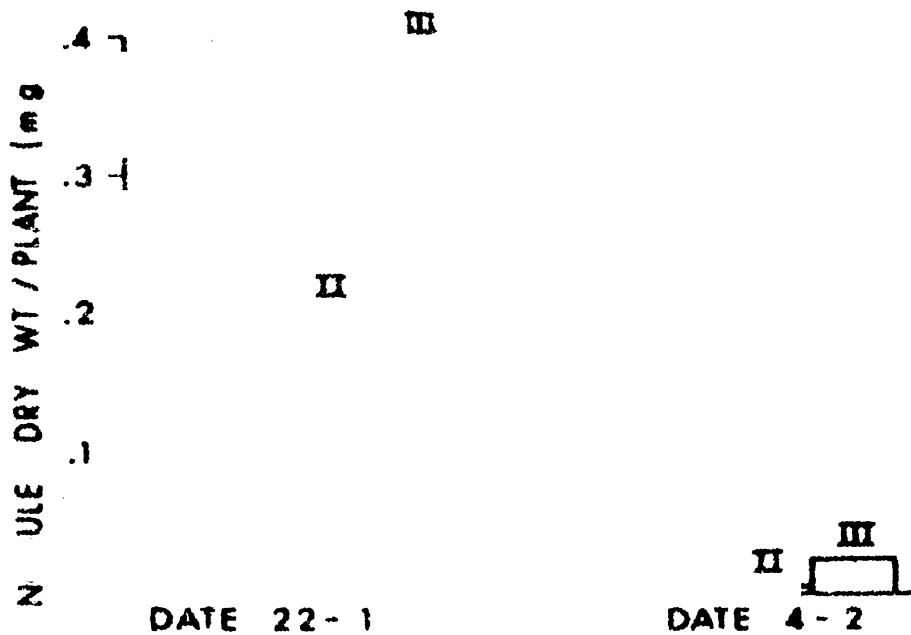


FIGURE 17

NODULE WEIGHTS ON PLANTS OF C.V. T-3  
AFTER I NO FLOWER REMOVAL (CONTROL )  
II FLOWER REMOVAL FOR THREE WEEKS  
(FROM 9-12) AND III CONTINUOUS FLOWER  
REMOVAL (FROM 9-12)



### CHAPTER III

#### The Development of Pods

##### Introduction and Methods.

The development of pods was studied in cultivars of early (JG-62 and Chaffa) medium (850-3/27 and L-550) and late (T-3 and G-130) duration groups. All the cultivars were planted on October 1, 1974. A sufficiently large number of flowers that opened on a particular day (as judged by the flower colour) were tagged. Flower-tagging was done on 26-11-74 in JG-62 on 2-12-74 in Chaffa, on 4-12-74 in L-550 and 850-3/27 on 23-12-74 in T<sub>3</sub> and on 27-12-74 in G-130. Periodic samplings of the developing pods were made at intervals of 8-10 days. In the initial sample 50 developing pods were sampled; in the subsequent samples 20-25 pods were used. The lengths of the peduncle and pedicel and length and breadth of the pods were recorded. The pods were then separated into pedicel, peduncle, pod cover and seed. Fresh weights of all the components were taken and seed number recorded. The samples were then dried in the oven at 80°C and dry weights were recorded.

#### Results and Discussion

The pedicel and peduncle reached their maximum length by about 7-8 days after anthesis. The weight per unit length of pedicel and peduncle continued to increase up to the 15-17th days after flowering in cvs Chaffa and JG-62 and 20-24th days in cvs L-550, 850-3/27, G-130 and T-3. During this period the pedicels and peduncles were growing in thickness; anatomical investigations showed that this thickening was associated with the differentiation of new vascular tissue and fibres.

The pods attained their maximum length and breadth by about 13-17 days after anthesis (Fig. 18).

In the first sample, 7-10 days after anthesis, the seed number per pod was higher than in subsequent samples. This fall in seed number per pod reflects the abortion of seeds, which took place during the first two weeks. Thereafter the number of seeds per pod remained more or less steady (Fig. 18).

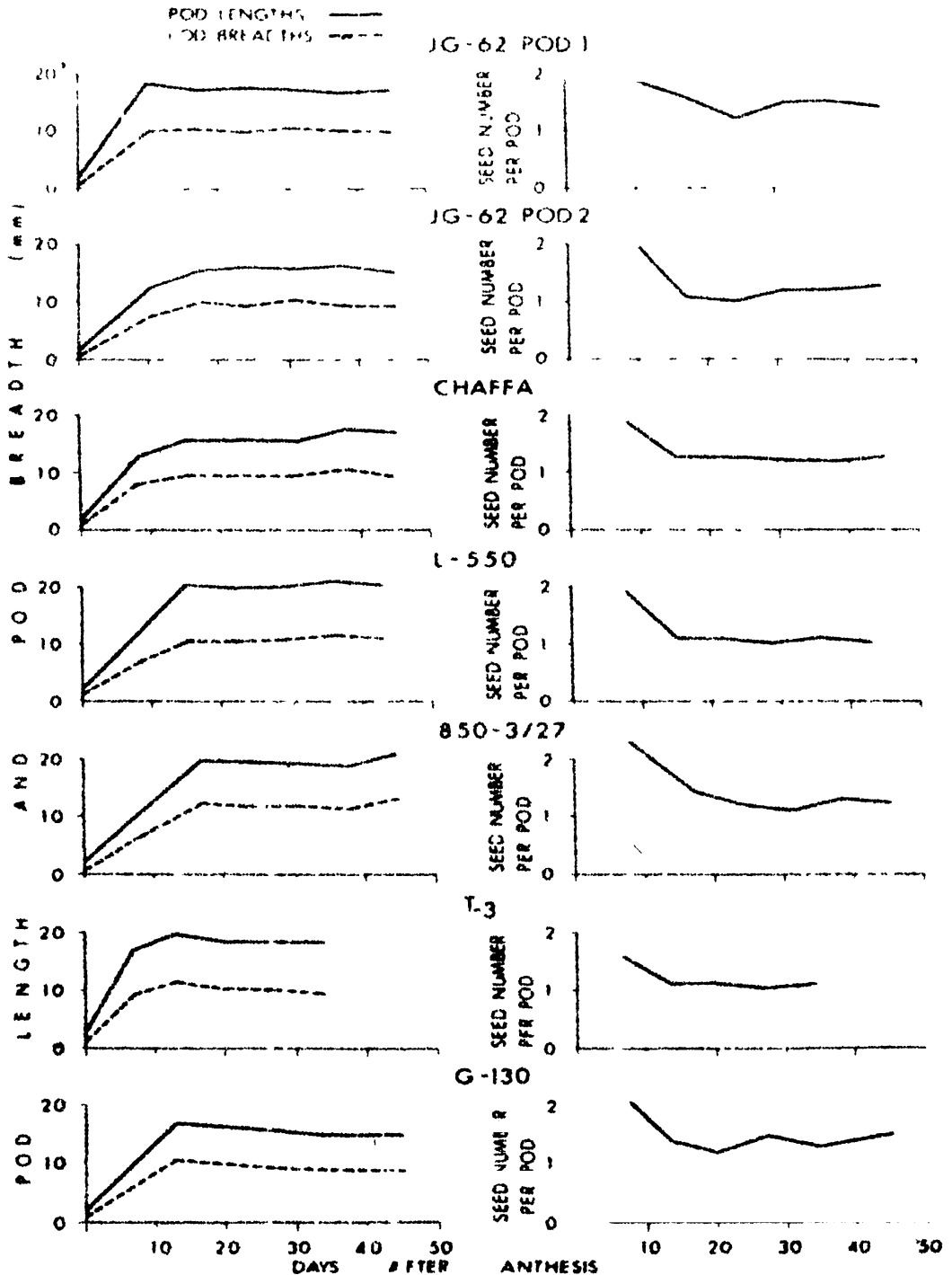
The progressive accumulation of dry weight in the seeds and pod walls are presented graphically in Figs. 19 and 20.

In the case of JG-62, a double-podded cultivar, there was a time difference between the development of the first (Pod<sub>1</sub>) and second (Pod<sub>2</sub>) pod. Generally the first formed pod (Pod<sub>1</sub>) added more dry matter both in the seeds and pod wall in the first 17 days after the opening of the flower and maintained this difference until the time of harvest.

The pattern of accumulation of dry matter in the seeds and pod walls of all the cultivars was more or less the same. The pod wall was the first to develop and added more dry matter compared with the seeds up to 15-17 days after anthesis. There was a rapid accumulation of dry weight in the seeds after the addition of dry matter to the pod walls had more or less ceased. The accumulation of dry weight in seeds continued up to 35-40 days in early and medium-duration cultivars, but more or less stopped after 25-30 days in the late-duration cultivars T-3 and G-130. The rate of accumulation of dry weight in the pod as a whole was calculated for different varieties. After attaining the maximum rate of dry matter

FIGURE 18

CHANGE IN LENGTH AND BREADTH OF PODS AND SEED NUMBER PER POD DURING POD DEVELOPMENT



**FIGURE 19**  
**FRESH & DRY WEIGHT OF DIFFERENT**  
**COMPONENTS OF A DEVELOPING**  
**POD IN CV 850-3/27**

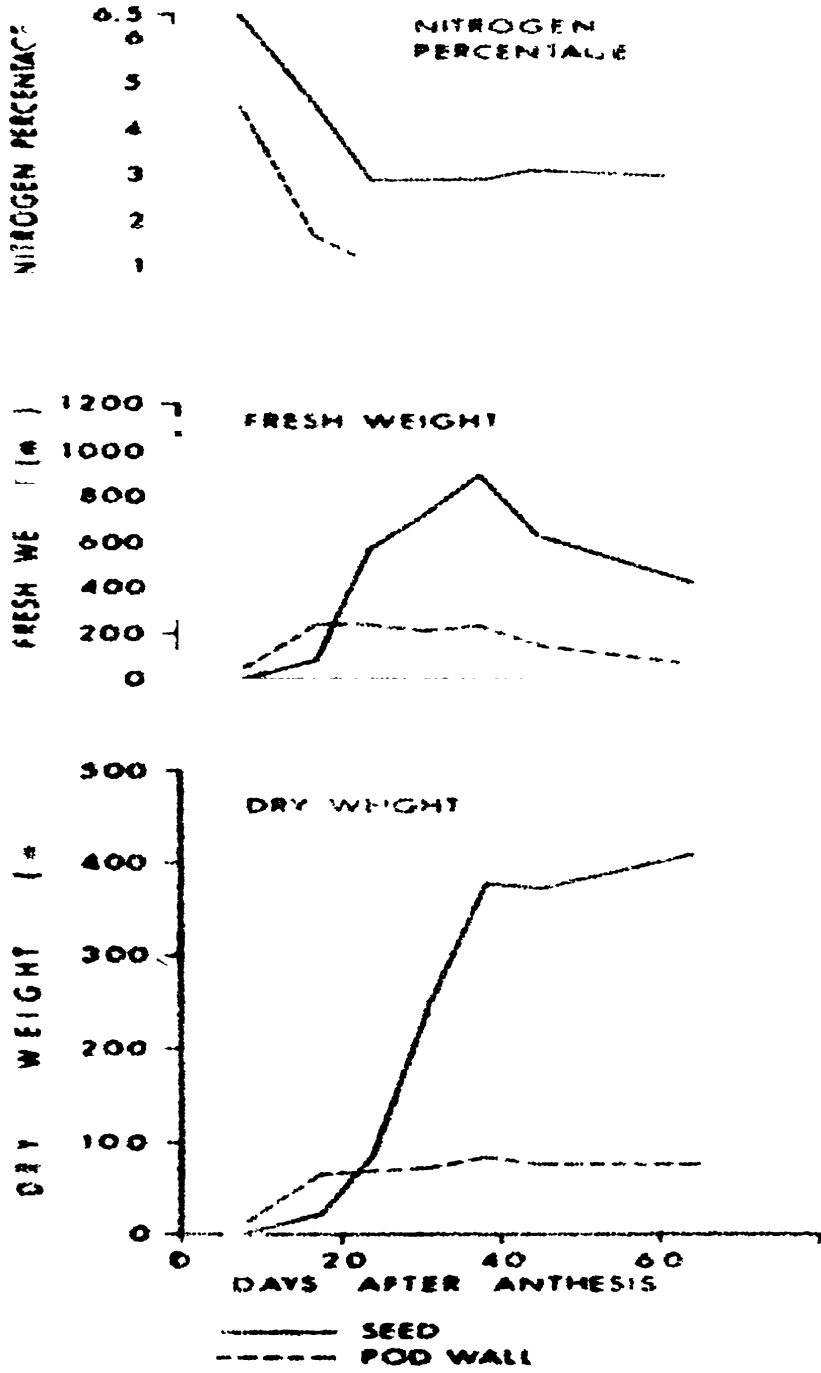
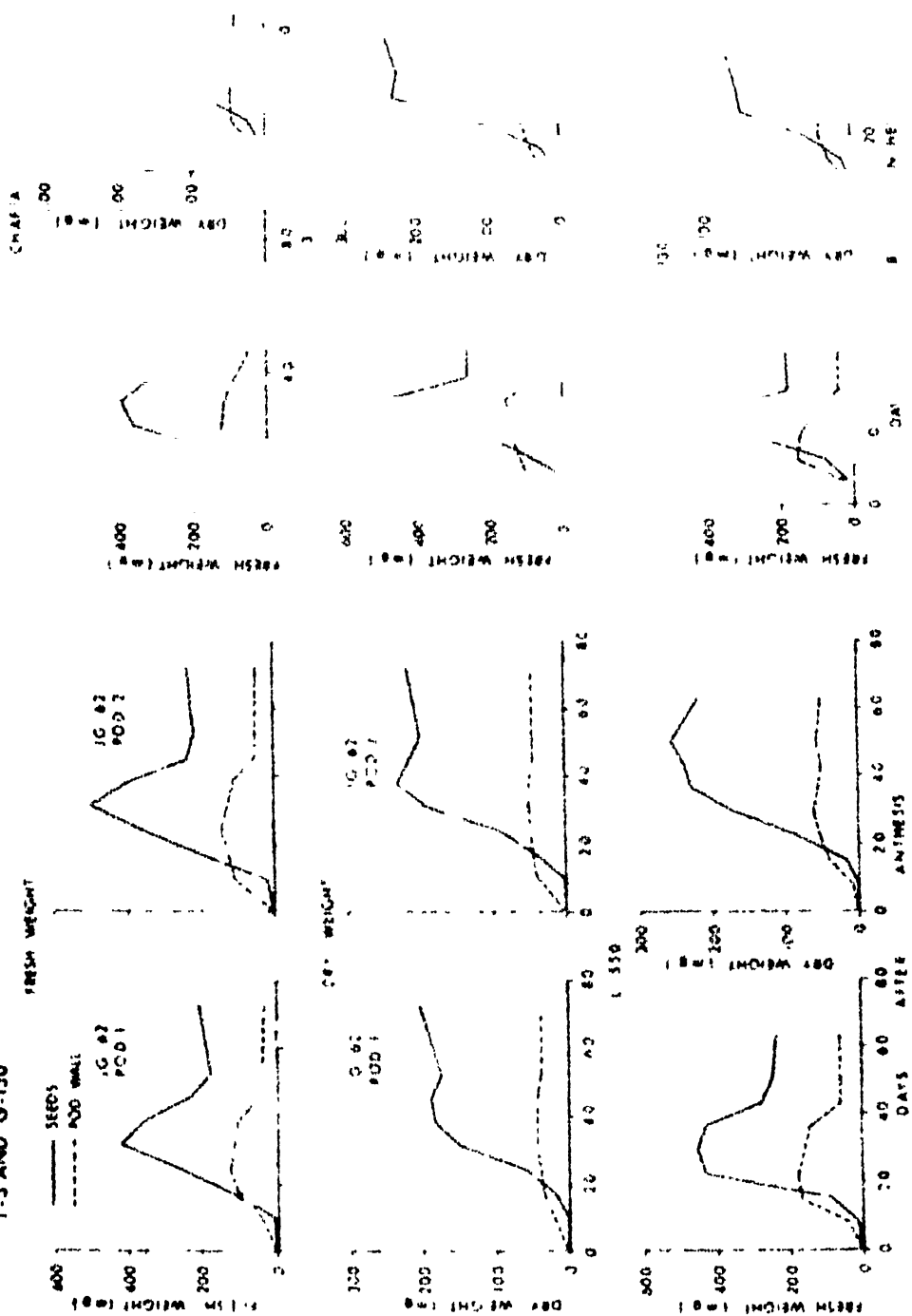




FIGURE 20  
 FRESH AND DRY WEIGHT OF DIFFERENT COMPONENTS  
 OF DEVELOPING PODS OF CVS JG-62, L-550, CHAFFA  
 T-3 AND G-130



addition to the pod, the rate gradually declined in some of the cvs (L-550, Chaffa and JG-62) but rather abruptly in cvs 850-3/27, G-130 and T-3 (Fig.21).

The progressive accumulation of dry weight in the pods of different cultivars is compared in Fig. 22. In the early stages of development of the pod (first sample) when most of the dry matter was added to the pod wall there was not much difference between the cultivars except in the case of JG-62 which had two developing pods per node. The accumulation of dry weight in different genotypes seemed to be related to the final seed size and seed number. Cultivars with bigger seeds (850-3/27) or more seeds per node (JG-62) added more dry matter to the pod during a given time compared with cultivars with smaller seeds. The pods of cultivars with bigger seeds also took longer to accumulate their maximum dry weight.

The time at which the seed or pod accumulated maximum dry weight was the time of the physiological maturity of the seed (by definition). There was a loss of fresh weight of the seed from that time onwards. After attaining the maximum fresh weight, the pod wall maintained its weight for a period of 3-4 weeks before it started losing weight along with the loss in fresh weight of the seeds.

The percentage of nitrogen in the developing pod walls and seeds of cv 850-3/27 was determined. In both, the percentage was highest at

FIGURE 21

GROWTH RATES OF DEVELOPING PODS

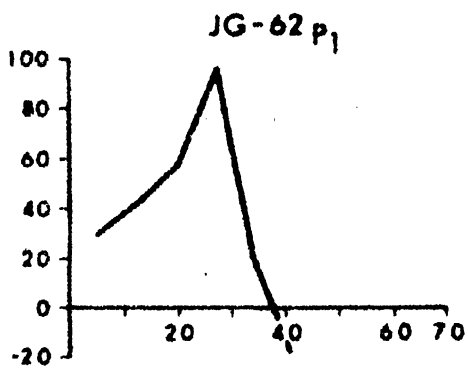
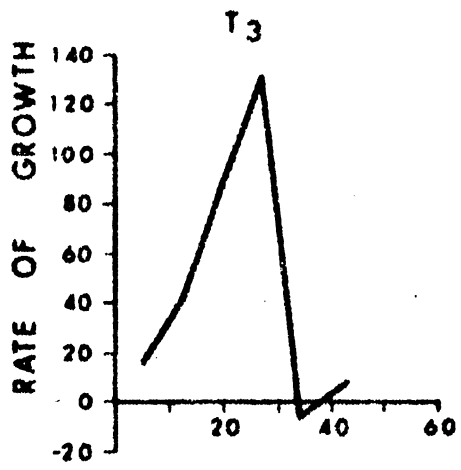
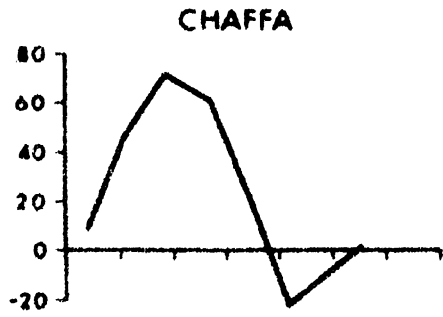
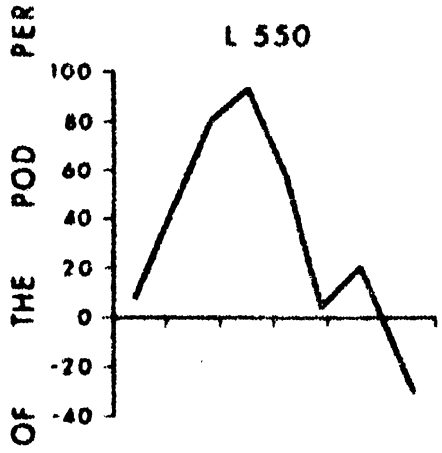
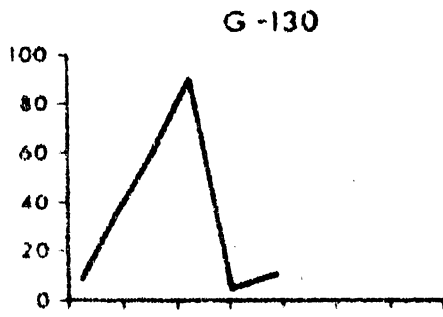
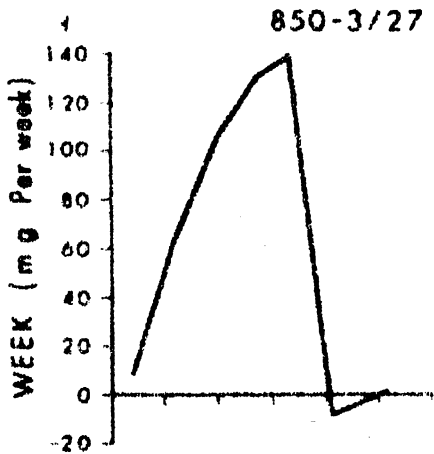
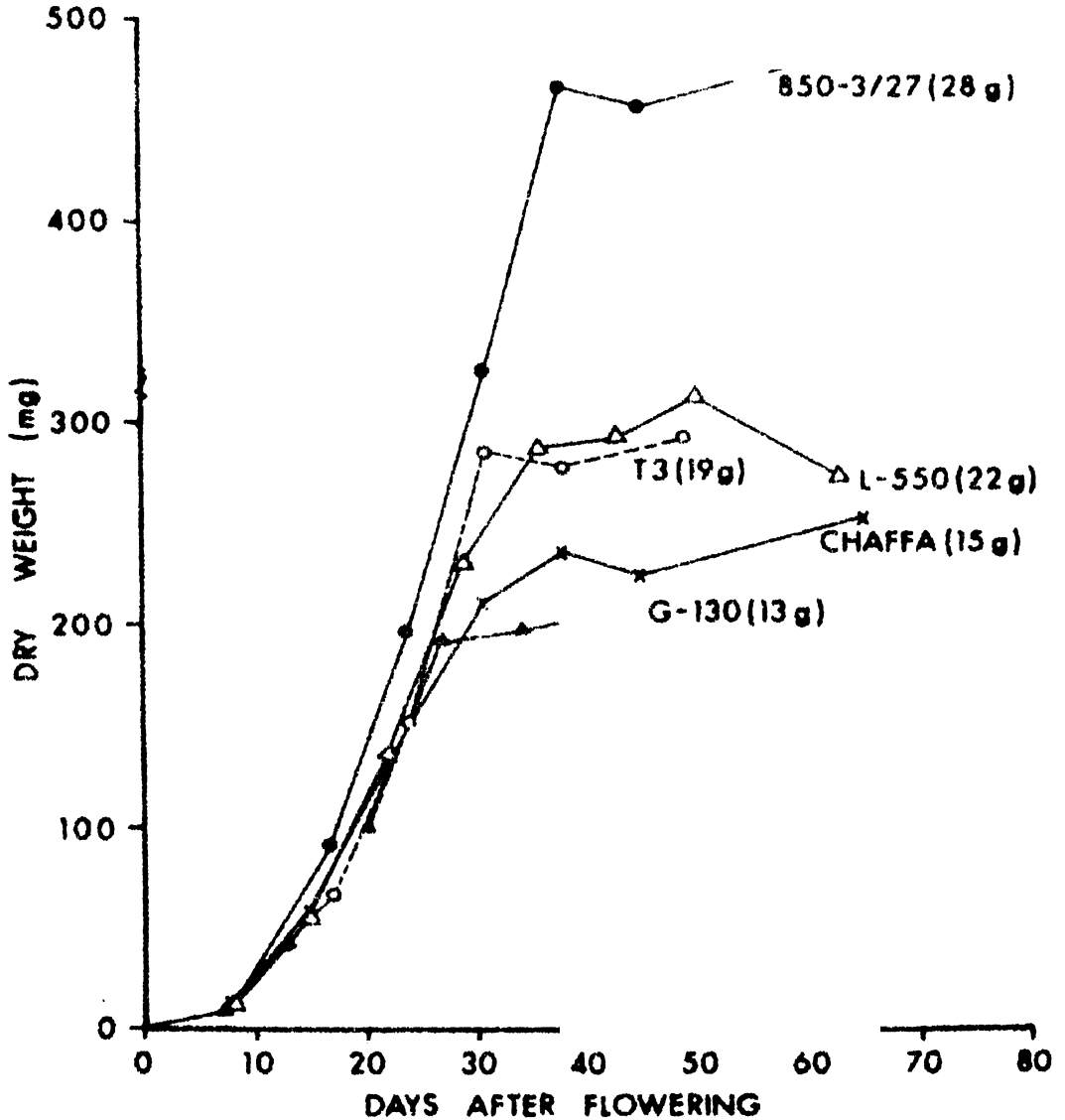


FIGURE 22

DRY MATTER ACCUMULATION BY DEVELOPING  
PODS IN DIFFERENT CHICKPEA VARIETIES (1974-75)

(100 SEED WEIGHTS SHOWN IN BRACKETS)



first and declined with the growth of the pod. It remained more or less unchanged after 24 days in the seed and after 31 days in the pod wall (Fig. 19). Thus during the grand period of growth of the seeds the accumulation of dry matter and of nitrogen take place in parallel.

## CHAPTER IV

### Effects of Seed Size on Crop Growth and Yield

#### Introduction

There is a considerable range of seed sizes within seed-lots of chickpeas and seeds of different sizes can be separated easily, for example by sieving. A small preliminary experiment was carried out to study the effect of seed size on growth and yield.

#### Methods

Seeds of three cvs, JG-62, 850-3/27 and T-3, were graded by sieving and small and large seeds of each cultivar were separated. The hundred seed weights (in gm) were as follows:

	<u>JG-62</u>	<u>850-3/27</u>	<u>T-3</u>
Small seeds	12.9	20.5	15.0
Large seeds	20.6	38.7	24.4

The seeds were sown on 6-11-1974 in black soil (ST-1 area). A randomized block design was employed with each treatment replicated three times. The plot size was 1.5x1.0m and spacing 30 x 10 cm. Plants of cvs JG-62 and 850-3/27 were sampled on 27-12-1974 during the flowering stage. Yield of all cultivars were recorded at the time of harvest (20-2-1975).

#### Results and Discussion

The larger seeds of all cultivars gave rise to larger seedlings and larger plants than the smaller seeds. The plants from the larger

Data taken shortly after the beginning of flowering on cvs JG-62 and 850-3/27 demonstrate that the plants derived from larger seeds were larger and had a higher leaf area (Table 14).

Yield data are shown in Table 15. In cvs JG-62 and T-3 there was no significant effect of seed size on yield but in cv 850-3/27 the larger seeds gave significantly higher yield, 35% more than the smaller seeds.

In many crops it has been found that larger seeds give rise to larger seedlings, but these do not always give higher yields because these differences are not maintained as the crop develops. And even if such increases can be achieved at a constant plant population, more relevant for practical purposes is the effect of seed grading on yield at a given seed rate. But only further empirical investigations can reveal whether in a given situation seed-grading of chickpeas will be of advantage.

Table 14. Effect of seed size on different components of plants of cvs JG-62 and 850-3/27 at the time of flowering.

	JG-62		850-3/27	
	Small seed	Large seed	Small seed	Large seed
Total dry wt./plant (gm)	2.1	2.6	2.5	4.2
Stem wt./plant (gm)	0.6	0.8	0.7	1.2
Pinna wt./plant (gm)	1.0	1.2	1.2	2.1
LAI	0.6	0.8	0.9	1.3

Table 15. Effect of seed size on yield (Kg./ha)

Cultivar	Small seed	Large seed
JG-62	1380	1275
850-3/27	1363	1845
T-3	1156	1302

LSD (0.05) = 328 Kg./ha



## CHAPTER V

### Phosphate Dusting Experiment

#### Introduction

The leaves, stems and pods of chickpeas are covered with glandular hairs which secrete an acidic exudate containing about 0.1% malic acid and 0.05% oxalic acid. The pH of this exudate is close to 2. It is not known what function, if any, this exudate has. One possibility is protection from attacks by pests. But whatever its primary function may be, it seemed possible for the following reasons that this exudate could be put to use in the phosphatic fertilization of the plants:

Much of the phosphatic fertilizer applied to soil is not available to plants owing to phosphate fixation. Furthermore the cheapest form of phosphate, namely rock phosphate, is more or less insoluble in normal soils and is therefore less efficacious than more expensive, soluble forms of phosphate. Rock phosphate is, however, solubulized at low pHs. Preliminary experiments in the laboratory showed that a synthetic chickpea exudate (0.1% malic acid + 0.05% oxalic acid), when shaken with rock phosphate solubulized over fifty times more phosphate than either distilled water or the same synthetic exudate neutralized to pH 7.

It is therefore seemed likely that if powdered rock phosphate were dusted onto chickpeas it would be solubulized by the acidic exudate; if this solubulized phosphate were then taken up by the plant it could provide a cheap and simple method of applying phosphate to chickpeas.

In this experiment the effect of dusting rock phosphate onto chickpeas growing in phosphate-deficient soil was compared with controls (no phosphate) and with soil application and dusting treatments using single superphosphate. An additional control was included which involved dusting rock phosphate onto the soil rather than the plants, so that if a response to rock phosphate were obtained the effects of the application to the plants could be distinguished from any possible effects of rock phosphate which fell onto the surface of the soil.

#### Methods

The trial was laid out in a 5 x 5 Latin Square design on newly developed land to which no fertilizer had been applied previously. There was a uniform basal application of  $ZnSO_4$  at the rate of 45 Kg./ha. No Nitrogen was applied. The plot size was 1.8 x 3.0 M and plant-to-plant spacings were 30 x 10 cm. An early cv, BEG-482, was used. The crop was sown on 11-11-1974 and a light irrigation was given immediately after sowing. Flowering began after 32 days. The following dusting treatments were given 23, 59 and 71 days after sowing.

1. Control (no dusting)
2. Dusting plants with single superphosphate
3. Dusting plants with rock phosphate
4. Dusting soil with rock phosphate
5. Basal application of single superphosphate at the rate of 450 Kg./ha.

## Results and Discussion

The data on yield and yield components are given in Table 16.

The overall yields were low and in all treatments plants showed symptoms of phosphorus deficiency such as pigmentation of the leaves and dropping of the pinnae.

The only treatment which gave a yield significantly different from the control was dusting of the plants with rock phosphate. The increase in yield over the control was small (17%), but sufficiently encouraging to suggest that further trials should be carried out on the effects of such dustings.

The small differences between the different phosphate treatments and the differences in pod number per unit area were not statistically significant. The most interesting aspect of these results is that under condition of visible phosphate deficiency, the basal application of super phosphate at the high rate of 450 kg/ha had no detectable effect on growth and yield. It seems necessary to conclude that although the phosphate was added to the soil it was not taken up by the plants. This phosphate was banded along with the seeds at a depth of about 5 cm. Soon after the germination of the seeds the surface of the soil dried up progressively and root growth and activity in the surface layer must have been very low; the phosphate was confined to these layers and may therefore have been inaccessible to the plants.

Table 16. Effects of different methods of applying phosphate on yield and yield components of cv BEG-482.

Treatments	Yield Kg./ha	Pod No. per m <sup>2</sup>	Seed No. per pod.	100 seed weight.
1. Control (no phosphate)	510	497	1.1	9.3
2. Basal single super-phosphate	553	576	1.0	9.3
3. Dusting plants with single superphosphate	548	512	1.2	9.2
4. Dusting plants with rock phosphate	604	559	1.2	9.3
5. Dusting soil with rock phosphate	575	553	1.1	9.5
LSD (.05)	82	N.S.	N.S.	N.S.

## CHAPTER VI

### Effects of Plant Population and Geometry of Planting

#### Introduction

The effects of plant population and geometry of planting depend on a number of factors including inter-plant competition and the abilities of different cultivars to respond to different micro-environmental conditions.

In crops grown under conditions where water and nutrients are not the main limiting factors, inter-plant competition generally involves a competition for light. The effects of spacing and geometry of planting can be understood mostly in terms of canopy structure and mutual shading. Under such conditions it has often been found that crops, e.g. soyabeans, planted in a grid pattern give higher yields than when they are planted in rows.

Under dry-land conditions in general, and especially in the rabi season when chickpeas are grown, water is not present in unlimited quantities. As the growth of the crop proceeds there is a progressive depletion of soil moisture (Chapter II). The positive response to irrigation which has been reported many times for chickpeas indicates that soil moisture is a limiting factor for growth and yield. Therefore interplant competition seems likely to involve a competition below ground for moisture in addition to competition above ground for light. Since very little is known about this underground competition, the effects of plant

population and planting geometry cannot be predicted on the basis of simple hypotheses which take into account the shoot system alone.

Some preliminary studies were made of the response of plants of these cultivars to different population-densities by planting them radially in a "wheel-spoke" design. The effects of the geometry of planting were investigated in another experiment where square ('grid') planting was compared with row plantings.

#### Methods

For the radial plantings these cultivars were used, Chaffa, 850-3/27 and T-3. They were sown on 6-11-1974 in 4 m. long rows which radiated from a centre point to a row-to-row spacing of 75 cms at the periphery. The plant-to-plant spacing within the rows was 10 cm. Each plot contained 8 rows and the 6 inner rows were treated as 6 replicates. At harvest each plant was collected and labelled separately, the numbers of primary, secondary and tertiary branches, the total plant dry weight, the yield components and the seed dry weight were recorded. The plants were harvested on 18-2-1975.

In the geometry of planting trial, two cultivars were used, Chaffa and BEG-482 at the following spacings (in cms) : 30 x 10, 17.3 x 17.3, 15 x 20, 20 x 10, 14,2 x 14,2, 10 x 10. The plots were 4 x 2 m. and were replicated 3 times. They were sown on 15-11-1974. At the time of harvest (20-2-1975) the yield, yield components and number of primary, secondary and tertiary branches per plant were recorded.

## Results and Discussion

### 1. Radial planting experiment

A mutual inhibition growth was observed between the rows even when the plants were not overlapping. Such interplant competition when the canopy was not closed strongly suggests that the competition between plants took place mainly below rather than above ground.

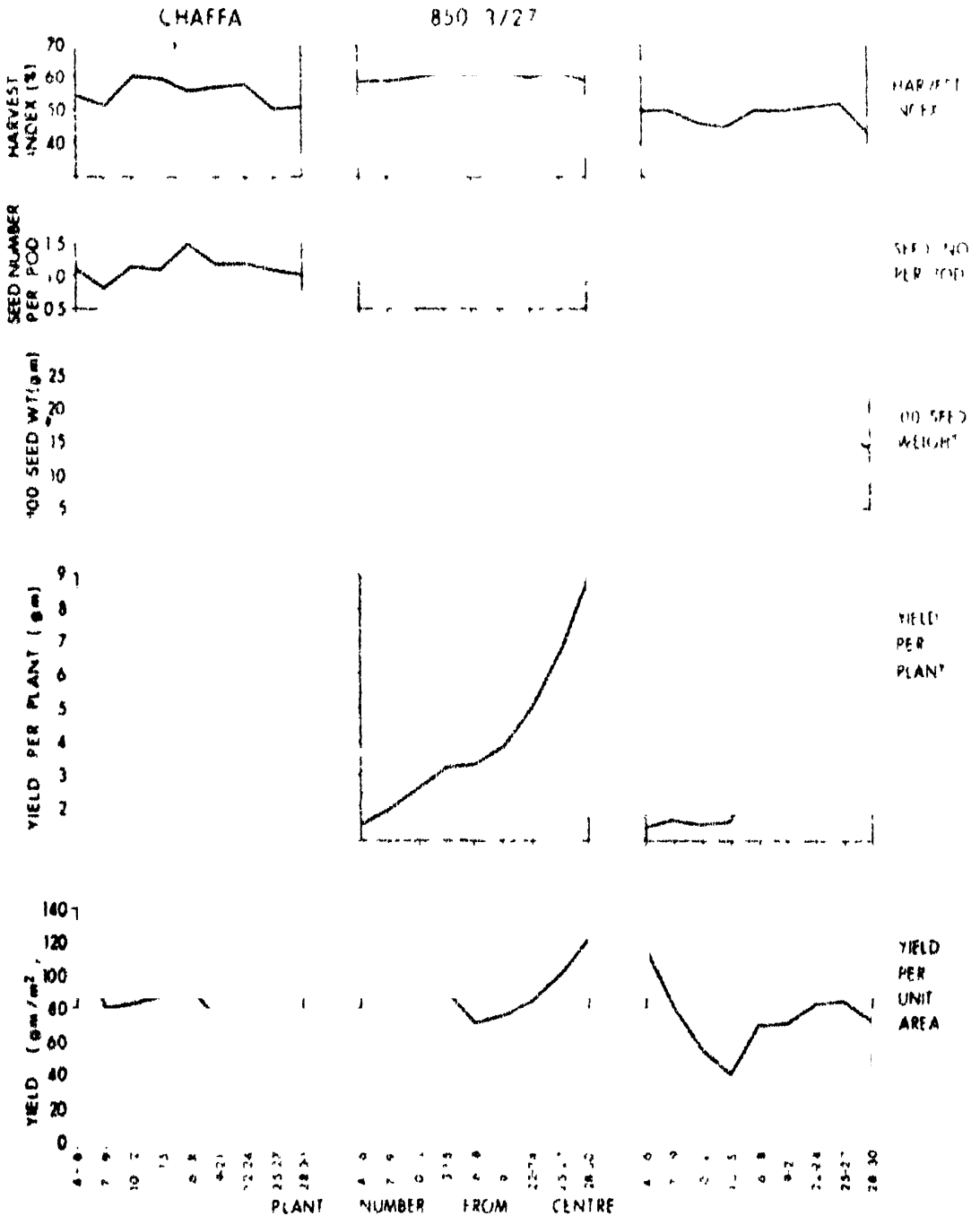
The responses of the cultivars to the increasing spacing was strikingly different. The yield per plant continued to increase in cv 850-3/27 right up to the widest spacing employed whereas in cv Chaffa a point was reached, when the rows were about 40 cm apart, beyond which further increases in spacing had little or no effect on the yield per plant. Cv T-3 showed an increased yield per plant with increasing spacing but not so strikingly as 850-3/27. Results averaged for three successive plants in all rows are shown in Fig. 23. The results from the first three plants have been omitted since they were at the border of the plot.

When the yield figures are expressed on the basis of yield per unit area, at the wider spacings cv Chaffa shows a fall with decreasing plant population, cv 850-3/27 a rise and cv T-3 little change (Fig. 23). All gave highest yields per unit area at the highest density.

In cvs 850-3/27 and T-3 as the spacing between rows increased, so did the number of primary, secondary and tertiary branches per plant (these data were not recorded for cv Chaffa). The number of pods per plant also increased in direct proportion to the size of the plants.

FIGURE 23

HARVEST INDEX, YIELD COMPONENTS AND YIELD OF CVS CHAFFA, 850-3/27 AND T-3 GROWN IN RADIAL PLANTINGS





The result was that the harvest index remained more or less constant over the whole range of spacings, as did seed number per pod and 100 seed weights (Fig. 23).

The differences between cultivars in their ability to respond to the wider spacings by putting on more growth and producing more pods can be thought of in terms of differences in plasticity. A greater plasticity means that a more stable yield would be obtained over a wider range of spacings. This might be important in the field conditions under which chickpea is often grown, where management is poor and plant-to-plant spacing is variable. No doubt the plasticity of different cultivars depends in part on their different durations, on the time of sowing and on the length of the growing season. But even within a given maturity group under given growing conditions, cultivars may differ in their plasticity and hence in their ability to yield well under the variable plant-to-plant spacings encountered in farmers' fields.

## 2. Geometry of Planting Experiment

This experiment involved not only a comparison of different geometries of planting but also compared the effect of three different population-densities, viz. 33, 50 and 100 plants/m<sup>2</sup>. As in the radial planting experiment it was found that the highest population-density gave the highest yield per unit area. The normal populations recommended in this region and used on the ICRISAT farm, viz. 33 plants/m<sup>2</sup>, seemed to be sub-optimal. An examination of the available literature has revealed that where higher populations have been tried in this region of India, higher yields have been obtained.

At the normal population-density of 33 plants/m<sup>2</sup> the rectangular plantings produced significantly higher yields than the grid (equidistant) method of planting. When the plant population was increased to 50 plants/m<sup>2</sup> the differences became insignificant (Table 17).

Table 17. Effects of different plant-to-plant spacings on yield of cvs Chaffa and BEG-482.

Spacings (cm.)	Plant population m <sup>-2</sup>	Yield gm/m <sup>2</sup>		
		Cultivars		Mean
		Chaffa	BEG-482	Spacings
30 x 10	33	342	376	359
20 x 15	33	379	380	380
17.3 x 17.3	33	296	338	317
20 x 10	50	353	421	387
14.2 x 14.2	50	370	440	405
10 x 10	100	446	497	472
Mean	-	365	409	

LSD (0.05)

Cultivars	N.S.
Spacings	26 gm/m <sup>2</sup>
Cultivars x spacings.	34 gm/m <sup>2</sup>
Populations	36 gm/m <sup>2</sup>

The finding that the square method of planting gave lower yields than row plantings agrees with results obtained with other crops grown in the dry season, for example with sorghum grown in the dry summer season in Israel and with sunflowers grown in the rabi season in India. One reason may be that the square-planted plants suffer less competition at first, and therefore put on more vegetative growth and consume more of the limited supply of soil moisture than the plants in rows; consequently they suffer more from moisture stress during the reproductive phase and yield is reduced.