Pulse Physiology

A Terminal Report
on
Responses of Pigeonpea and Chickpea to Phosphorus on an Alfisol and Vertisol in Peninsular India

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International Crops Research Institute for the Semi-Arid Tropics
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PART 1

Responses of Chickpea and Pigeonpea to Spot Placements of Nitrogen and Phosphorus on a Deep Vertisol With and Without Irrigation

1. Introduction

Responses to nitrogen and phosphorus application in chickpea and pigeonpea have been critically reviewed at the two International Workshops on these crops held recently at ICRISAT, (1-4).

In field experiments at ICRISAT Center these two crops did not respond to application of N and P205 upto 100 kg/ha, when broadcast or placed in trenches about 30 cm below the soil surface, both in the presence and absence of irrigation (5, 6). Increases in grain yield ranging from 15 to 26% have been obtained in chickpea at ICRISAT (7, 8) after foliar fertilization with N and P individually or combined in spray solutions at the pod filling stage. In pigeonpea, no responses to foliar fertilization have been reported (9). The responses to foliar fertilizer application were, however, not consistent.

The lack of or low responses to applied N and P fertilizers may be due to one or more of the following reasons:

i) The available N and P content in the soil considered to be "low in N and P" was in fact sufficient to meet the requirement for the growth of chickpea and pigeonpea at the present yield levels harvested in these two crops at ICRISAT Center.

ii) Roots of pulses are capable of extracting P from soil low in available P.

iii) Fertilizers broadcast on the soil surface were not effective because they do not come in physical contact with active roots which are growing away from surface layers and/or fixation of P by the soil and losses of N related to soil moisture.

The effect of nitrogen on the growth of pulses needs to be examined in relation to the fixation of N by nodules. This report examines the relationship between P uptake and the possibility that the lack of response is because N and P are available in sufficient quantities in the soil.

Sheldrake and Saxena (10) have shown that, on Vertisols under receding soil moisture more than 40% of the roots in chickpea were distributed below 30 cm depth after flowering and that the proportion of root below this depth increased to more than 50% during the pod filling stage. Total uptake of P from the soil ranged between 5 to 7 kg/ha at a yield level of 1500 kg/ha (2, 9). Even if the fallen leaves are taken into consideration, the total uptake of P during the growth period does not exceed 12-16 kg/ha, a situation which is discussed later.

An example of the vertical distribution of available P in a Vertisol to a depth of 1 m is given in Table 1. The total amount of available P in the top 90 cm was around 24 kg P/ha. Therefore, in spite of the low availability of P in the soil (< 3 ppm), the total amount of available P in the effective rooting zone does not seem to be insufficient to meet the requirement of chickpea at the yield level generally obtained in non-irrigated chickpeas at ICRISAT Center, when the effective contribution of mycorrhiza for P uptake is presumed.

A preliminary report from ICRISAT suggests that pigeonpeas are very efficient in extracting P from the soil compared with sorghum. The amount of P absorbed by pigeonpea in a pot experiment exceeded the total amount of available P in the soil. However, more work is needed both in chickpea as well as pigeonpea on the above aspect.

The experiments reported here were conducted to investigate whether the lack of response to N and P in chickpea and pigeonpea is due to an insufficient amount of nutrients in the active root zone. Methods of fertilizer application in combination with irrigation treatments were studied.

2. Materials and Methods

Field

The soil was a deep Vertisol (ICRISAT Center, BM3B). The average chemical characteristics of soil up to a depth of 85 cm were as follows:

Available N (by alkaline $KMnO_4$ method): 59.7±8.0; range 38-75 ppm

Available P (by Olsen method): 6.6±6.0; range 0.5-34 ppm

EC: 0.62±0.21; range 0.35-1.17 m mohs/cm

pH: 8.07; range 7.70-8.25

The vertical distribution of available P is shown in Table 1.

According to the criteria adopted in the soil chemistry laboratory at ICRISAT, this field was characterized as low in available N, medium in available P and moderately saline for growing chickpea and pigeonpea.

Design

Main plots were irrigated and non-irrigated, with three replications. To the irrigated plots three irrigations each of 5 cm were applied on the 26th, 49th and 76th day after sowing chickpea and on the 26th, 75th and 102nd day after sowing pigeonpea.

The sub-plots were fertilizer treatments and consisted of the application of single superphosphate (SSP, 40 kg/P_2O_5/ha) as spot placement at depths of 20, 45 and 70 cms alone and in combination with urea (20 kg/N/ha). The treatments were allotted in a randomized block design.

The method of fertilizer placement is shown in Fig. 1. Holes were made to different depths using a crow bar. Fertilizers were applied in the hole by inserting a polyethylene tube with a funnel at the upper end. After fertilizer application, the holes were covered with wet soil. One hole was made in the center of 4 plants on each ridge. In this way, 200 holes were made in each plot for the spot placement of fertilizers before seeding.

Sowing was done on October 31, 1980 and a 5 cm post-sowing irrigation was given to ensure uniform germination. The details of harvest are given below:

Chickpea (cv. CPS-1)

Non-irrigated : Feb. 5 7, 1981
Irrigated : Feb.19 22, 1981

Pigeonpea (cv. BDN-1)

Non-irrigated: Mar. 11 14, 1981
Irrigated : Mar. 19 21, 1981

Plant samples were oven dried, weighed and ground for the analysis of N, P, K, Na and Zn contents.

3. Results and Discussion

Vertical distribution of soil moisture in non-irrigated plots on two different dates is shown in Fig. 2. It is clear that even after harvest, moisture content below 30 cm was above field capacity (around 28% by wt.), probably because of the effect of the nearby lake.

Chemical characteristics of the irrigation water used from the nearby lake are shown in Table 2. The amount of nutrients applied with each irrigation was 0.75 - 1 kg N/ha and less than 0.05 kg P/ha. The total amount of nutrients applied through irrigation water was around 3 kg of N and less than 0.2 kg of P per hectare in all four irrigations. The irrigated treatments, therefore, received about 10%

more N compared to non-irrigated treatments, whereas the supply of phosphorus due to irrigation was negligible.

a) Chickpea

i) Analysis of harvest data

Significant differences and interactions were observed due to irrigation and fertilizer treatments (Tables 3 and 4). There was no significant effect of the depth of fertilizer on the characters measured except 100 seed weight, total P uptake and P content in grain. The data are shown in Figs. 3-5.

Increase in mean grain yield due to irrigation was 75%, due to P application 8.0% and due to combined application of N and P was 13.9%. A large increase in grain yield of 32% in response to combined placement of N and P was observed in the non-irrigated treatment. This was probably because the nodules regressed and/or ceased to be active earlier in this treatment. This will be explained in later paragraphs.

In the irrigated treatment, the combined application of N and P resulted in a larger response in dry matter of shoot than in grain and hence decreased the harvest index (H.I.).

Increase in the 100 seed weight from 14.3 to 15.4 g and grain protein from 13.0 to 19.6% occurred in response to irrigation. The effect of soil salinity in decreasing 100 seed weights and protein content of chickpea grain has been reported recently (14). Chickpea is classified as a plant sensitive to salinity, the level at which yield begins to decline being about 1 mmhos/cm (15).

Data in Fig. 4 suggest that moderate levels of salinity may lead to a reduction in 100 seed weight and grain protein content without appreciably reducing yield. Irrigation appeared to ameliorate the effects of salinity on seed weight and protein content.

Protein content in grain increased significantly from 15.7 to 17.5% when N and P were applied together. No significant increase in P content of the grain was observed in response to application of P. However, a significant uptake in the total N and P was observed by the joint application of N and P in the non-irrigated treatment, and by the application of phosphorus alone in the irrigated treatment (Fig. 5). The total uptake of P, P content in the grain and 100 seed weight were significantly affected by the depth of fertilizer placement (Tables 3 and 4). Total P uptake and P content in the grain were highest when fertilizer was placed at a depth of 45 cm, compared with 70 cm and 20 cm respectively (Fig. 6). There was no significant difference in N uptake with different depths of placement. This indicates that perhaps the most suitable depth for maximum P uptake may be around 45 cm, whereas N applied as a spot placement was absorbed equally well irrespective of the depth of placement between 20 and 70 cm. Fertilizer placed at 70 cm decreased 100 seed weight from 15.1 g to 14.3 g.

ii) Growth pattern analysis

The response to irrigation of growth and N and P uptake apparent after 50% flowering, but differences in nodule growth due to irrigation appeared even earlier (Figs. 7-10). Nodules continued to increase and maintain themselves during the reproductive stage, except during podfill for a short period after irrigation (Fig. 7). In the non-irrigated treatment, in spite of the fact that the moisture content in sub-soil was sufficient for plant growth (Fig. 2), nodule senescence was fairly rapid. This suggests that adequate moisture in the uppper layers of the soil is necessary for continued nodule growth and activity.

In the irrigated treatment nodule growth was encouraged with P application, but it was not effectivp when N was applied together with P. Similar though not significant results were observed in the non-irrigated treatment. Changes in pattern of total dry weight and N and P uptake were quite similar to each other (Figs. 8-10). In both irrigated and non-irrigated plots the N and P content decreased during later part of the reproductive growth. This decrease appears to be related to the loss in dry matter and nutrient content as a result of leaflet drop (Fig. 11 and Table 5).

The dry weight in fruits increased almost linearly with time in irrigated and to some extent in non-irrigated treatments. In the non-irrigated treatment there was no net uptake of N and P in fruit parts in the later part of the reproductive phase (Figs. 9 and 10). In the non-irrigated plants it appears that there was little translocation of N and P from vegetative to fruit parts close to maturity. This result agrees with the remarkable decrease in green leaves during the mid-ripening period in this treatment when the total dry matter continued to increase. A comparable decrease was not observed in irrigated plants (Fig. 11).

The effect of N on increasing the total dry matter at all stages of growth of irrigated and non-irrigated chickpea were observed when N and P were applied together. The response was also evident in fruit parts but in the non-irrigated treatment only; whereas response to P alone was noticed in the irrigated treatment. The pattern of N and P was similar to the pattern of dry matter accumulation in response to fertilizer treatments.

The N concentration in the leaves remained around 5% throughout the reproductive phase in the irrigated treatment but declined sharply in the non-irrigated treatment after flowering (Fig. 12). Higher dry matter production in irrigated plots may be a consequence of a better nitrogen status. N and P concentration with irrigation were always higher than those in the non-irrigated plants throughout the reproductive phase, except for P in the stems (Fig. 13). In the non-irrigated P + N treatment, the N concentration of leaves and fruit parts were higher throughout the growth period than in the other treatments (Figs. 14 and 15). On the other hand, N concentration in the nodules decreased with fertilizer application, probably due to the positive effect of P on nodule growth (Fig. 7) and the negative effect of nitrogen on N2 fixation in both the irrigated and non-irrigated treatments (Fig. 16).

The P concentrations of leaves and fruit parts responded to P application in a manner similar to N, but this effect was statistically not significant.

iii) Absorption rate and loss of nitrogen and phosphorus

As already illustrated in Figs. 8-10, maximum dry matter and N and P uptake occurred at 82 days in the non-irrigated and at 95 days in the irrigated treatments, after which there was a sharp decrease in dry matter, primarily due to leaf fall toward harvest. Consequently, 20-30% of total dry matter, 50-55% of N and 35-50% of P were lost during the ripening process (Table 5). A higher proportion of N and P than total dry matter was lost in all treatments indicating that N and P in chickpea leaves may not be translocated from vegetative into reproductive parts before leaf fall. In pigeonpea such a translocation seems to take place as discussed later. Interestingly, under the non-irrigated condition the loss of nutrients was highest in the control "nil" treatment, whereas with irrigation the highest loss was from the "P+N" treatment, suggesting that spot placed fertilizer in the non-irrigated treatment might reduce the losses of total dry matter, N and P more than in the irrigated situation.

Based on the results of Figs. 5, 9 and 10, absorption rates of fertilizers were estimated by the balancing method (Table 6). In non-irrigated plots N applied together with P stimulated the rate of absorption of P both at the time the plants had attained their maximum dry weight and at harvest. It should be noticed that when N and P were applied together in the irrigated treatment nearly 40% of the applied SSP had been absorbed by the time of maximum growth. If the amount of N fixation was assumed to be similar between control and "P+N" treatment, more than 80% of the urea was absorbed by the time of harvest.

These observations suggest that deep and spot placement of P could result in marginal increases in grain yield of chickpea even when the level of available P in the soil profile may appear sufficient. Spot application of N together with P appears to be effective in increasing grain yield and grain protein content under receding soil moisture. Further, spot application of fertilizer might increase the efficiency of fertilizer use.

iv) Summary

Insufficient nutrients in the active root zone as a possible reason for the lack of response to N and P in chickpea was examined by deep and spot placement of fertilizers (SSP and urea) with and without irrigation. Grain yield increased by 75% due to irrigation, by 8.0% due to P alone and 13.9% when N and P were applied together. In non-irrigated plants, grain yield increased by 32% in response to combined N and P placement, which probably compensates for early cessation of nodule activity in this treatment. Weight of 100 seeds increased from 14.3 g to 15.4 g and grain protein content from 13.0% to 19.6% when irrigation was supplied, perhaps because of the

ameliorating effect of irrigation on salinity. Combined N and P application significantly increased grain protein from 15.7% to 17.5%. Under the non-irrigated condition, spot application of N plus P stimulated the P absorption rate.

b)

i) Analysis of harvest data

The grain yield, N and P uptake and grain protein content of pigeonpea responded to irrigation in a manner similar to that of chickpea though the magnitude was smaller (Tables 7 & 8; Figs. 17, 18 and 19). The vegetative and early reproductive growth was reduced immediately following the first and second irrigations (Fig. 20) probably because of temporary anaerobic conditions as explained later.

The effect of irrigation in ameliorating the effects of linity are seen in the increased protein content of the grain in irrigated pigeonpea. A similar effect was observed in chickpea as discussed earlier (Fig. 4 & 19).

Combined application of N and P irrespective of depth of application resulted in very small increases in grain and straw yields as well as N and P uptake (Fig. 17 & 18). The differences between control (nil) and "P+N" were not significant, but were so between "P" and "P+N". The placement of SSP alone may depress the growth of pigeonpea at the vegetative and podding stages. This is discussed later.

In the non-irrigated treatment the application of nitrogen increased straw yield more than grain yield, resulting in the decrease in harvest index (H.I.) (Fig. 17).

With irrigation the protein content in grain was not affected by depth of fertilizer placement whereas in non-irrigated plots, "P+N" placed at 20 cm increased the protein content to 18.1% from an average of 16.7% at 45 cm and 70 cm.

ii) Analysis of growth patterns

Pigeonpea leaves, especially the new ones, became yellow and remained so for several days after the first and second irrigations, probably because of the harmful effect of excess moisture (anaerobic condition) on N fixation and/or the uptake of other nutrients (Fig. 20, & Fig. 25, 26). Similar symptoms were observed with chickpea a few days after the first irrigation. Compared to pigeonpea this symptom disappeared earlier in chickpea. It is likely that such nutrient deficiencies might have been the reason that growth was retarded at the vegetative and flowering stages. Measurement of N and P contents in different parts of pigeonpeas two weeks after the second irrigation (88 days after sowing), reveal that the concentrations are in fact lower than those in the non-irrigated treatment (Fig. 25 & 26). After the third irrigation, however, when soil cracking had already commenced in the non-irrigated treatment, N and P contents in irrigated pigeonpea remained higher than those in the non-irrigated plots resulting in a significant increase in N and P uptake in irrigated pigeonpea at harvest (Table 8, Fig. 18 & 20). The increase in the contents of N and P in green leaves and stems in both irrigated and non-irrigated treatments at harvest might be attributed to the perennial nature of pigeonpea (Fig. 25 & 26).

As in the case of chickpea the dry weight of green leaves decreased remarkably while the total dry matter was still increasing in the non-irrigated treatment (Fig. 21). It remained more or less constant in the irrigated treatment.

In the non-irrigated treatment the dry matter not only decreased in vegetative parts but also in fruit parts from maximum total dry matter at 118 days after sowing to that found at harvest. Even with irrigation there was no increase in the dry matter of the fruit parts during the maturing stage (Figs. 20 and 21) except in the "P+N" irrigated treatment (Fig. 22) indicating that in this experiment physiological maturity was earlier than the stage at which the crop was harvested.

Application of SSP alone suppressed the growth and N and P uptake both at the vegetative and podding stages irrespective of the irrigation treatment (Fig. 22-24). The negative effect of the depth of SSP placement at 20 and 45 cm depth was observed in the non-irrigated treatment only (Fig. 27). However, at harvest the final grain yield was similar to that in the control (nil) treatment. In the presence of urea the negative effect of SSP was not apparent. The reasons for the negative effect of SSP alone on the growth of pigeonpea and the alleviation of its harmful effect when applied along with urea are not clear. Recent studies with several tropical legumes in solution culture have shown that pigeonpea is very sensitive to "excess" P concentration (Bell, R.W. & Edward, D.G.: Personal communication). More work is needed on this aspect.

There was no significant difference in N and P concentrations in leaves, stems and fruit parts due to fertilizer treatment, except in the leaves and stem at the stage just before flowering (Figs. 28-30).

III) Absorption rate and loss of nitrogen & phosphorus

Apparent absorption rate of N and P in the "N+P" treatment was about 28% and 5%, respectively, at harvest as estimated by the balancing method. However, there was no differnce in N and P uptake between the control (Nil) and the "P+N" treatment (Figs. 23 & 24) during intermediate growth. Perhaps because of the retarding effect of SSP on the growth of pigeonpea, the apparent absorption of N and P in the "P" treatment was negative.

The losses of total dry matter and N and P in the crop were mainly due to leaf fall during the ripening process (Table 9). The loss of total dry matter was 24 to 45%, of N 18-36% and of P 8 to 25% during the last 2-3 weeks before harvest. On an average, the losses were low in the irrigated treatment probably because the regrowth was more effective compared to the non- irrigated treatment. By contrast with chickpea, losses of N and P were lower than the loss in dry matter, suggesting that in pigeonpea N and P in senescent leaves might have been more effectively translocated to the stem and other parts prior to their fall.

Losses were also small in the fertilizer treatment in both irrigation treatments. Especially with irrigation, the losses in dry matter from plants were least in the N+P treatment. This treatment might be favourable for continuous ratoon growth.

It may be concluded on the basis of the above observations in rabi pigeonpea that:

a) On deep Vertisol, where moisture in the sub-soil layer remains high until harvest (Fig. 2), irrigations at early stages of growth could retard the vegetative and early reproductive growth, probably due to inhibitory effects of excess moisture (anaerobic condition) on the nodule activity and/or on nutrient uptake. However, late irrigations, at a stage when soil cracking begins in non-irrigated treatments, promotes reproductive growth. Growth at the early and late vegetative stages of pigeonpea (BDN-1) appears to be more sensitive to excess moisture than does chickpea (CPS-1).

b) Deep and spot placement of SSP alone may have a negative effect on the growth of pigeonpea on a Vertisol with a medium level of available P. Spot application of urea together with SSP appears to overcome the negative effect.

iv) Summary

The grain yield (19.4%) and N and P uptake of rabi pigeonpea responded to irrigation. These responses were, however smaller than those in chickpea. This lower response in pigeonpea might be because pigeonpea is more sensitive than chickpea to anaerobic conditions that prevail after irrigation.

Grain protein content increased from 17.5% to 19.0% due to irrigation, perhaps because of the ameliorating effect of irrigation on soil salinity.

Application of SSP alone suppressed the growth of pigeonpea at the vegetative and flowering stages, which was overcome when urea was applied together with SSP. Application of urea with SSP increased grain yield by 5.7% and 7.7% compared to the control (nil) and the "SSP" alone treatment, respectively. The combined application of P+N also resulted in increase in straw weight and N and P uptake. Protein and P contents in the grain did not increase in response to fertilizer application.

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Table 1. An example of vertical distribution of available P in a Vertisol.

Depth	avail-P (ppm)	bulk density	P kg/ha
0 - 15 cm	3.0	1.3	5.9
15 - 30 cm	2.5	1.4	5.3
30 - 60 cm	2.0	1.4	8.4
60 - 90 cm	1.0	1.4	4.2
		Total	23.8

Table 2. Chemical analysis of the water used to irrigate the pigeonpea and chickpea plots.

Days after sowing	0	26	49	76	102
pH	7.0	7.9	7.9	8.0	7.6
EC m.mhos/cm	0.5[illegible]	0.65	0.78	0.67	0.65
Cl^- (ppm)	44	4[illegible]	58	53	62
SO_4^{2-} ,,	[illegible]0	10	15	20	30
NO_3^--N ,,	0.[illegible]	0.[illegible]	0.5	0.7	0.7
Total-N ,,	[illegible]	[illegible]	[illegible]	1.2	1.3
K^+ ,,	3.0	2.[illegible]	2.0	4.0	4.0
Na^+ ,,	101	121	164	126	121
Total-P ,,	Nil	N[illegible]	Nil	Nil	Nil*

0.1 ppm)

Table 3. Grain and straw yield (kg/ha), HI, hundred seed weight, total uptake of N and percent protein and P content in chickpea in different fertilizer treatments.

Irri.	Depth of spot placement	Fertilizer treatment	Kg/ha Grain	Kg/ha Straw	H I.	100 seeds weight (g)	Total N uptake (kg/ha) Maximum*	Total N uptake (kg/ha) at Harvest	Total P uptake (kg/ha) Maximum*	Total P uptake (kg/ha) at Harvest	In Grain (%) Protein	In Grain (%) P
Non irrigated												
-	20 cm	none	1559	1553	50.3	14.23	83.2	42.7	12.7	7.87	12.8	0.45
	..	+P	1623	1731	48.3	14.43	98.1	51.6	14.0	9.32	12.2	0.44
	..	+N+P	[illegible]	[illegible]	50.5	15.47	113.6	51.4	16.1	8.79	14.6	0.46
	45	[illegible]	[illegible]	1460	48.3	14.47	86.7	37.5	13.1	7.45	12.8	0.50
	..	+P	1441	1533	48.4	14.33	79.4	41.7	12.0	7.94	12.7	0.47
	..	+N+P	2045	2062	49.7	[illegible]	109.4	66.3	15.4	10.79	14.1	0.47
	[illegible] cm	none	1331	1462	47.7	13.23	92.9	37.7	14.1	6.86	11.5	0.44
-	..	+P	1695	1727	48.1	13.53	95.5	45.1	14.3	8.43	11.8	0.47
-	..	+N+P	1760	1873	48.3	14.23	115.7	52.1	15.2	8.52	14.8	0.49
LSD (0.05)							25.3		3.3			
Irrigated												
+	20 cm	none	2631	2337	53.2	15.47	161.7	92.4	18.0	11.40	18.6	0.41
+	..	+P	2808	2763	50.6	15.43	217.5	108.8	23.7	15.24	18.7	0.44
+	..	+N+P	2865	2927	49.4	15.30	227.0	110.4	24.7	13.28	19.6	0.41
+	45 cm	none	2839	2489	53.8	15.87	205.4	97.6	24.7	13.87	19.5	0.45
+	..	+P	3041	2657	53.6	15.87	213.3	112.7	23.7	14.30	19.8	0.44
+	..	+N+P	2920	3081	48.9	15.53	225.0	113.0	25.8	14.82	21.2	0.47
+	70 cm	none	2680	2389	53.0	14.93	190.4	94.2	20.9	11.13	19.4	0.42
+	..	+P	2871	[illegible]	50.8	14.90	226.2	105.5	24.2	13.35	18.7	0.43
+	..	+N+P	2746	3063	47.5	15.03	287.3	110.6	33.4	14.33	20.9	0.47
LSD (0.05)			366	354	3.7	1.06	77.8	12.1	9.8	2.07	1.7	0.06

*Maximum uptake by the plant, 82 days after sowing in non-irrigated, 95 days after sowing in irrigated treatments.

Table 4 Analysis of variance for the chickpea characteristics obtained at harvest

Source of variation	d.f.	Yield Grain	Yield Straw	H.I.	Total uptake N	Total uptake P	100 Seed Weight	In Grain Protein	In Grain P
Replication	2	2.2[illegible]	1.36	1.19	3.25	12.54	7.23	0.02	0.36
Irrigation	1	4[illegible]8.71**	36.77*	1.12	277.73**	269.73**	131.59**	201.29**	1.35
Error	2		-		-	-	-	-	-
Depth of placement	2	1.0[illegible]	[illegible]	1.82	1.33	3.46*	9.33*	1.73	3.67*
Irri. x Depth	2	1.03*	0.14	0.88	0.37	0.68	1.49	1.94	0.04
Fertilizer levels	2						[illegible]		1.60
Fertilizer Effect	1	11.88*	3[illegible].97***	5.76*	42.57***	25.95***		8.55**	
Nitrogen Effect	1	2.60	12.69**	1.57	6.92*	0.61		30.51***	
Irri. x Fertilizer	2					0.91		0.80	0.16
Fert.effect x Irri.	1	1.3[illegible]	2.31	6.77*	0.64		1.77		
N effect x Irri.	1	6.0[illegible]*	0.13	8.60**	2.75		2.64*		
Fertilizer x Depth	4	0.49	1.42	0.69	1.12	2.39	0.76	0.66	1.20
Irri. x Depth x Fertilizer	4	1.0[illegible]	0.38	0.13	1.6[illegible]	1.42	0.33	0.59	0.91
Error	30-32	-	-	-		-	-	-	-

Significant at the level of * 5%, ** 1%, *** 0.1%.

Table 5. Losses in total dry matter, Nitrogen and Phosphorus during Ripening Process of Chickpea.

(Loss % of Maximum*)

Irrigated	Fertilizer treatment	Total dry matter	N	P
Non-irrigated	None	26.9	55.1	44.6
	P	22.1	49.3	36.2
	P+N	20.6	49.9	39.9
average		23.2	51.4	40.2
Irrigated	None	21.4	49.0	43.0
	P	25.0	50.2	40.1
	P+N	29.7	54.8	49.8
average		25.4	51.3	44.3

(* 82 days after sowing for non-irrigated
95 days after sowing for irrigated).

Table 6 A. Absorption Rate* of SSP-P(%) by Chickpea.

Fertilizer	Non-irrigated		Irrigated	
	at 82 days	at harvest	at 95 days	at harvest
P	1.1	6.7	15.3	12.4
P+N	14.4	11.3	38.7	11.5

6 B. Absorption Rate* of Urea-N (%)** by Chickpea at Harvest.

Non-irrigated	Irrigated
[illegible]	83.0

$$\text{Absorption Rate} = \frac{\text{P or N absorbed (at applied plot - at "None" plot)}}{\text{P or N applied}} \times 100$$

** Same level of N fixation between "None" and "P+N" is assumed.

Table 7. Grain and straw yield, harvest index (HI), total N and P uptake and protein and P content of grain in pigeonpea in field BM-3B in the 1980/81 Rabi season

Irrigation	Depth of Spot Placement	Fertilizer	Yield (kg/ha)		H.I.	Total N Uptake kg/ha		Total P Uptake kg/ha		in Grain (%)	
			Grain	Straw		at Max*	at Harvest	at Max*	at Harvest	Protein	P
−	20 cm	None	1811	2500	42.1	131.4	74.4	13.0	10.3	17.8	0.42
−	,,	P	1963	2606	43.1	86.6	81.0	10.9	11.0	18.0	0.40
−	,,	P+N	1940	2905	40.3	109.7	84.4	13.9	10.7	18.1	0.40
−	45 cm	None	1793	2487	42.0	102.1	74.8	12.8	9.8	17.6	0.40
−	,,	P	1895	2665	41.6	84.8	78.5	10.8	10.7	17.6	0.41
−	,,	P+N	2149	3188	40.3	110.3	86.7	13.7	12.5	16.9	0.42
−	70 cm	None	2048	2731	42.9	102.5	83.3	12.5	11.6	17.9	0.41
−	,,	P	1877	2623	41.8	96.4	74.4	11.9	10.1	17.1	0.39
−	,,	P+N	1976	3151	38.7	87.1	77.6	11.0	10.9	16.5	0.40
+	20 cm	None	2197	2891	43.2	135.2	93.5	16.6	12.7	17.8	0.39
+	,,	P	2432	3488	41.5	134.2	104.6	16.6	14.7	18.8	0.43
+	,,	P+N	2574	3636	41.8	123.1	115.2	15.4	15.3	19.1	0.42
+	45 cm	None	2456	3568	40.7	137.1	114.1	17.6	15.1	19.0	0.41
+	,,	P	2174	3139	41.1	115.8	100.8	14.1	12.8	19.1	0.40
+	,,	P+N	2271	3013	43.1	107.8	102.3	13.6	13.4	19.3	0.41
+	70 cm	None	2295	3201	41.9	109.1	102.7	13.8	13.4	19.9	0.40
+	,,	P	2026	2918	41.1	98.2	93.2	11.4	12.3	19.0	0.41
+	,,	P+N	2410	3517	40.7	120.7	110.0	15.0	15.1	19.0	0.43
	(LSD 5%		358	696	3.3		15.9		2.4	1.2	0.05)

(* 118 days after sowing)

Table 8. Analysis of variance for the pigeonpea characteristics measured at harvest

Source of Variation	d.f.	Yield		H.I.	Total Uptake		in Grain	
		Grain	Straw		N	P	Protein	P
Replication	2	2.10	1.53	2.59	1.04	3.00	77.08*	27.17*
Irrigation	1	95.30*	6.97	0.07	45.36*	64.85*	1027.3***	3.48
Error	2	-	-	-	-	-	-	-
Depth of Placement	2	0.23	0.01	0.80	0.38	0.09	0.02	0.85
Irri. x Depth	2	1.23	0.58	0.02	0.06	0.49	5.03*	0.58
Fertilizer used	2							0.24
Fertilizer Effect	1	0.43	2.10	2.52	0.49	0.59	0.41	
Nitrogen Effect	1	4.99*	5.58*	1.94	5.21*	5.21*	0.30	
Irri. x Fertilizer	2				0.34	0.18		1.40
Fert.Effect xIrri.	1	0.47	0.82	0.73			1.56	
N Effect x Irri.	1	0.47	0.77	5.38*			1.20	
Fertilizer x Depth	4	1.48	1.11	1.00	1.91	1.44*	2.09	0.27
Irri. x Depth x Fertilizer	4	1.65	1.61	0.46	1.84	2.98	0.15	0.93
Error	27-32	-	-	-	-	-	-	-

Table 9. Losses of total dry matter, nitrogen and phosphorus as % of maximum at 118 days after sowing during the ripening process of pigeonpea

Irrigation	Fertiliser	Total Dry Matter	N	P
-	None	45.0	35.5	24.8
-	P	36.8	27.3	15.8
-	P+N	39.6	33.7	21.2
average		40.5	32.2	20.6
+	None	31.6	28.8	21.8
+	P	29.7	26.4	14.5
+	P+N	23.8	18.6	8.2
average		28.4	24.6	14.8

Fig. 1. Method of spot placement of fertiliser in the field.

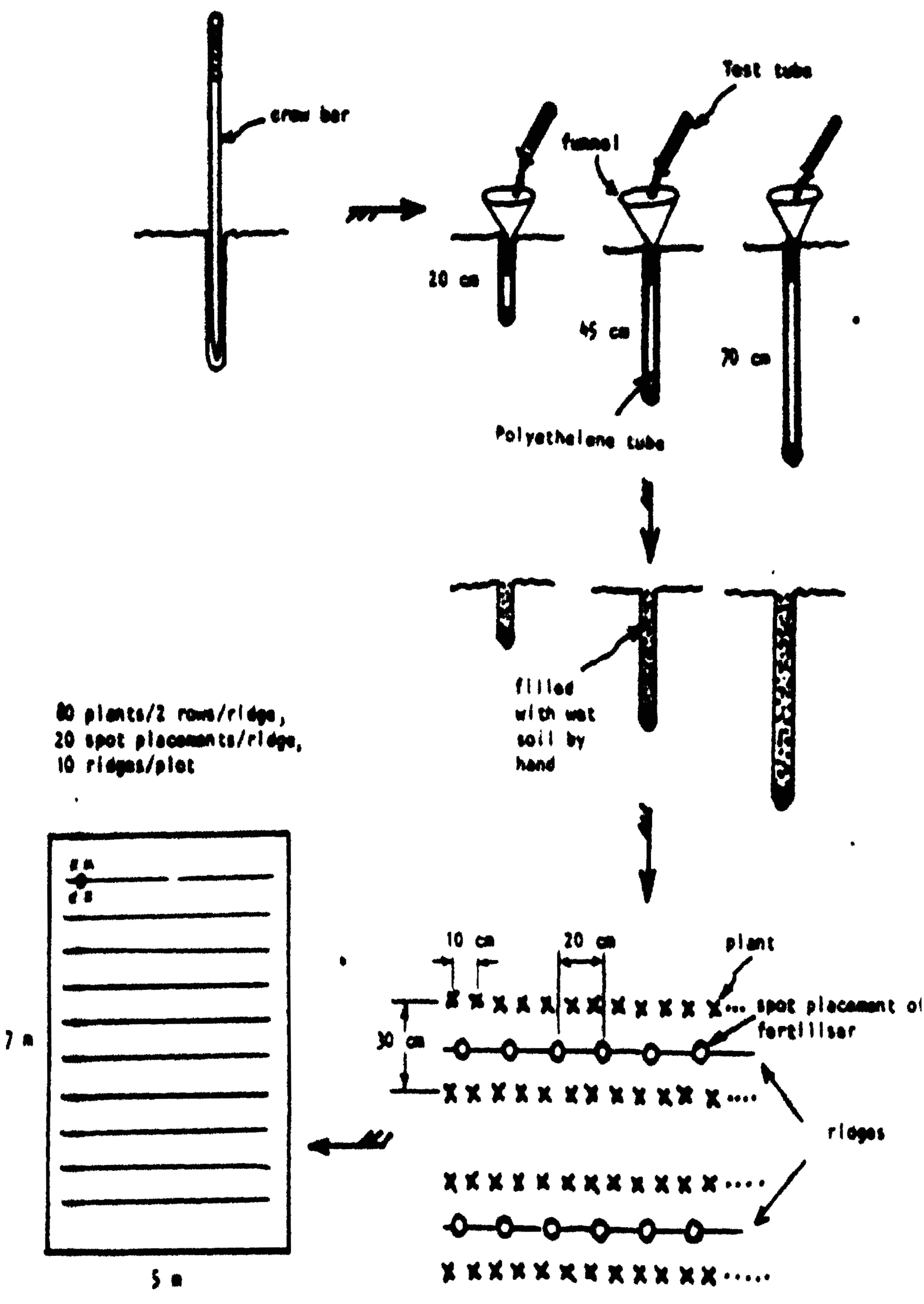


Fig. 2. Distribution of moisture in the soil profile (80/81 rabi, BM 38 at ICRISAT Center)

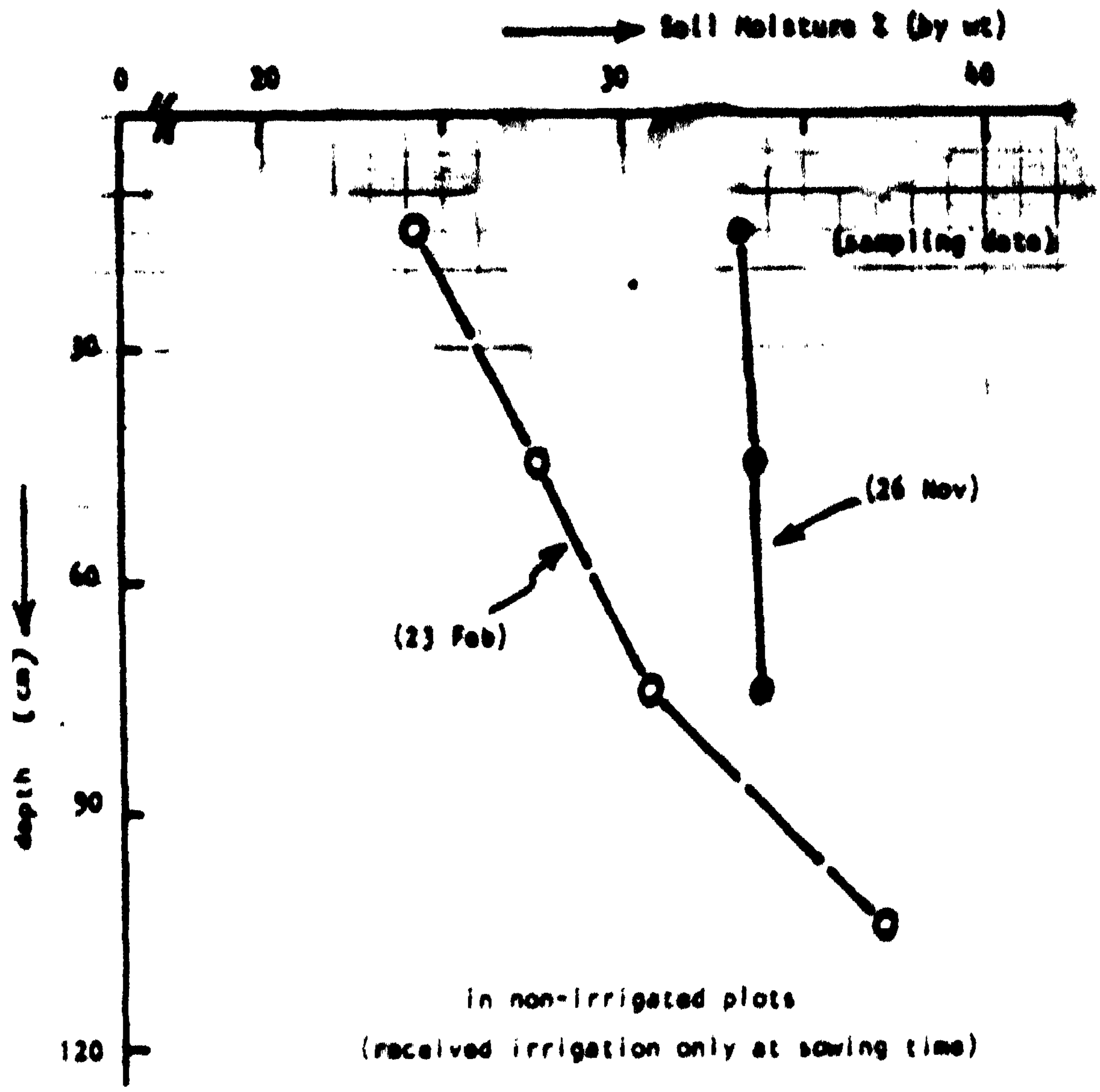


Fig. 3. Response of grain and straw yield of chickpea (CPS-1) to N and P placements with and without irrigation

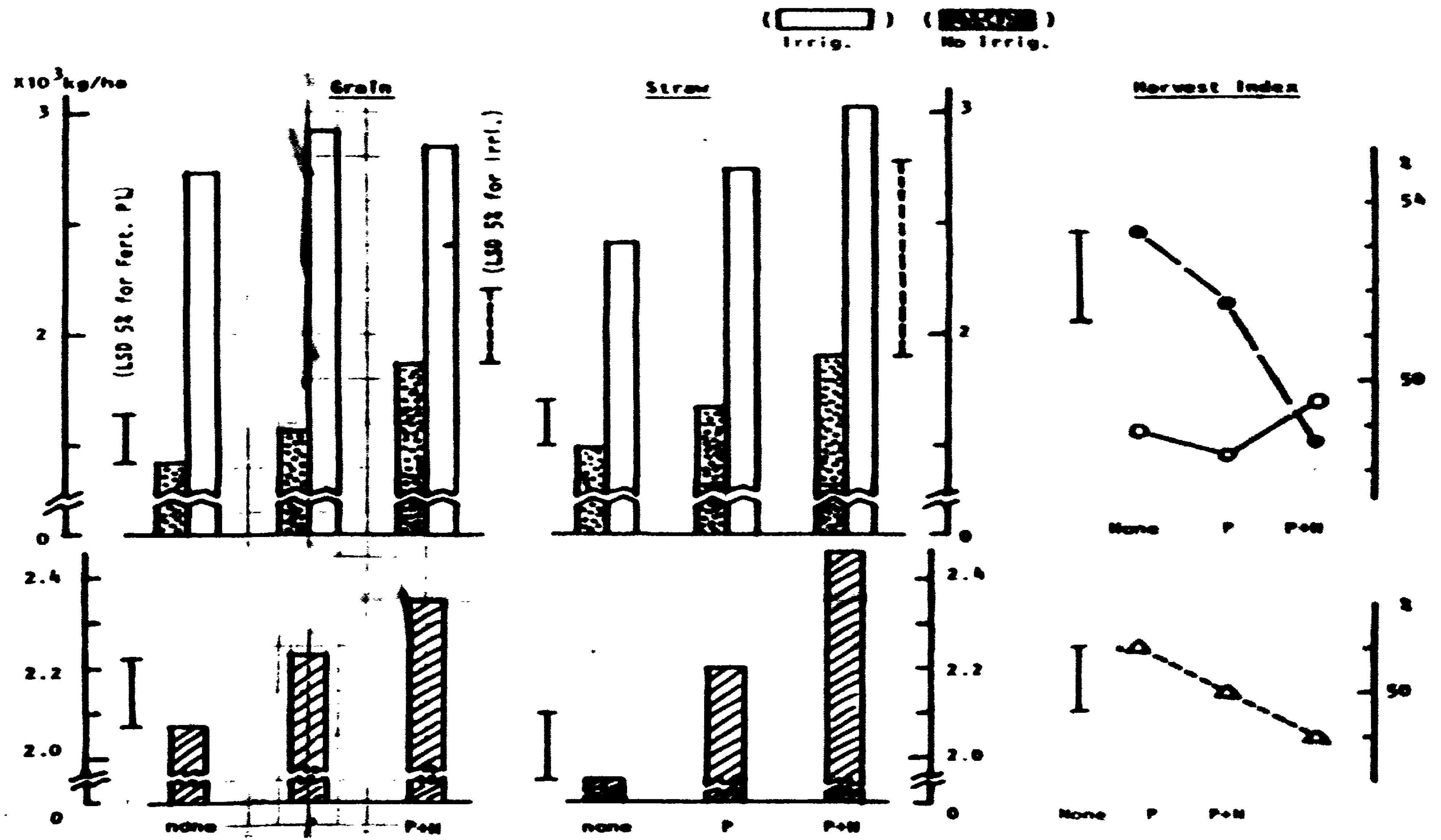


Fig.4. Response of 100 seed weight and grain protein and P to placement of P and N with and without irrigation

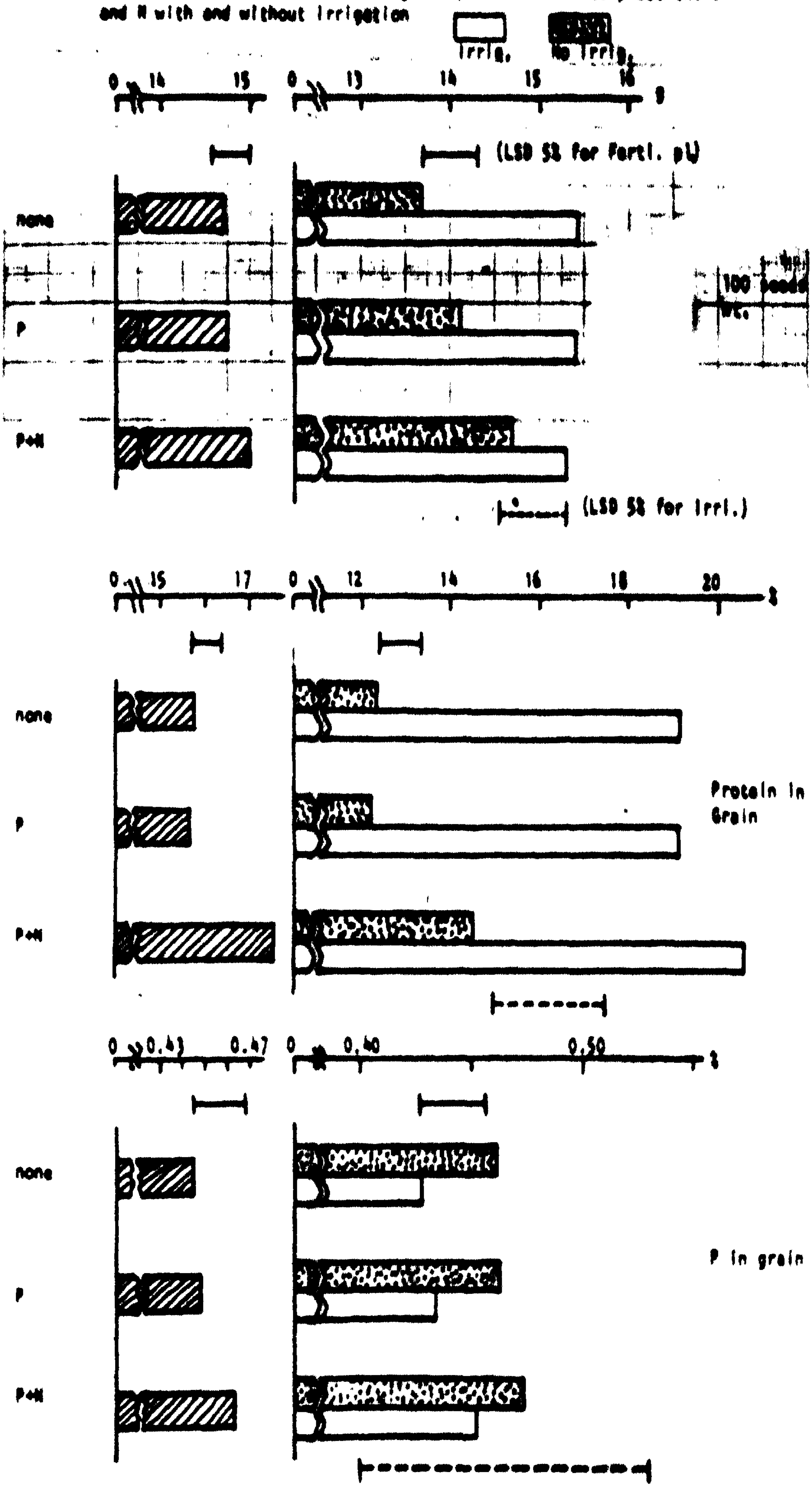


Fig. 5. Total uptake of N and P by chickpea at harvest with and without irrigation

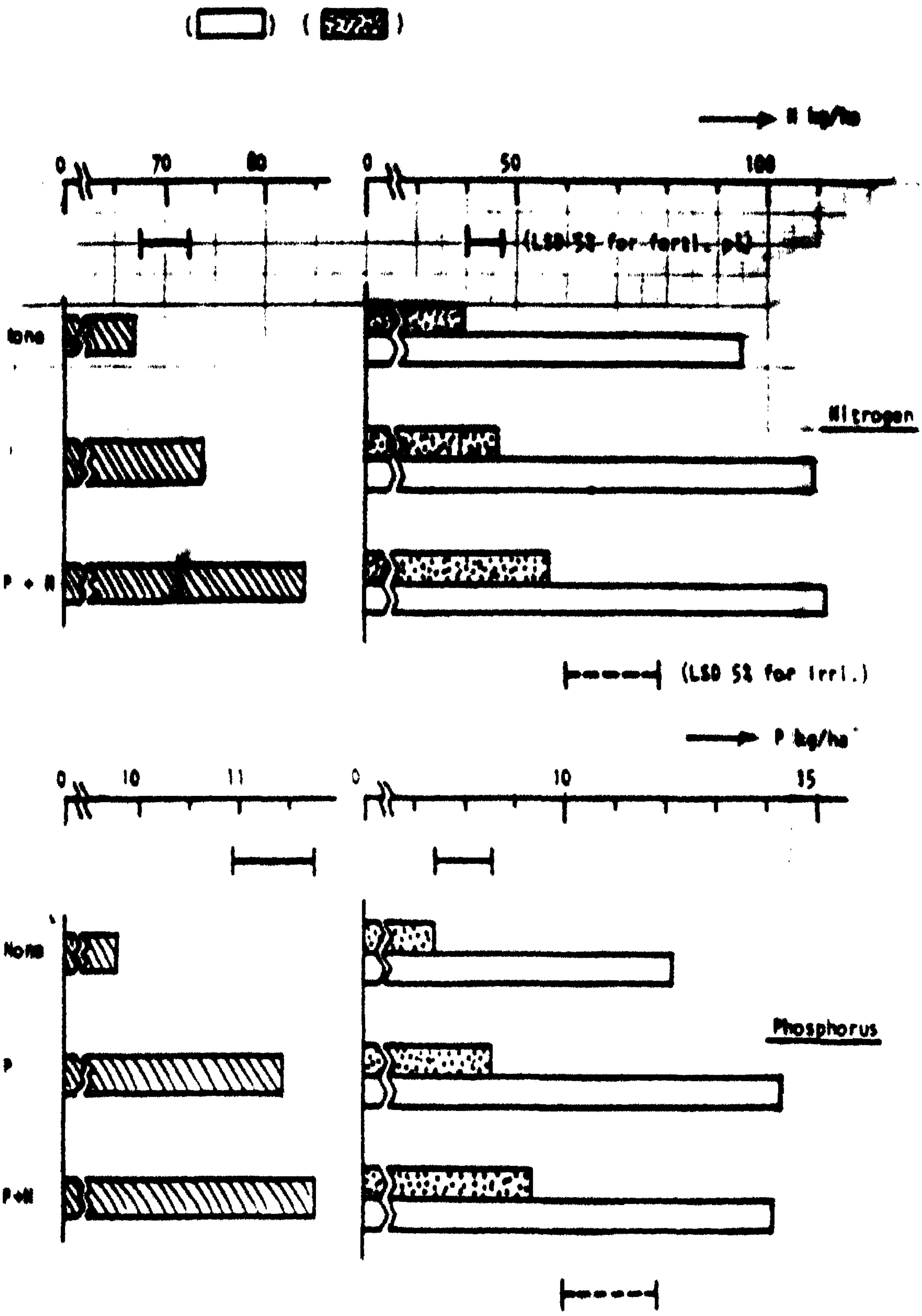


Fig. 6. Effects of depth of fertilizer placement on the total uptake of N and P and the P content in chickpea at harvest with (o--o--o) and without (o—o—o) irrigation

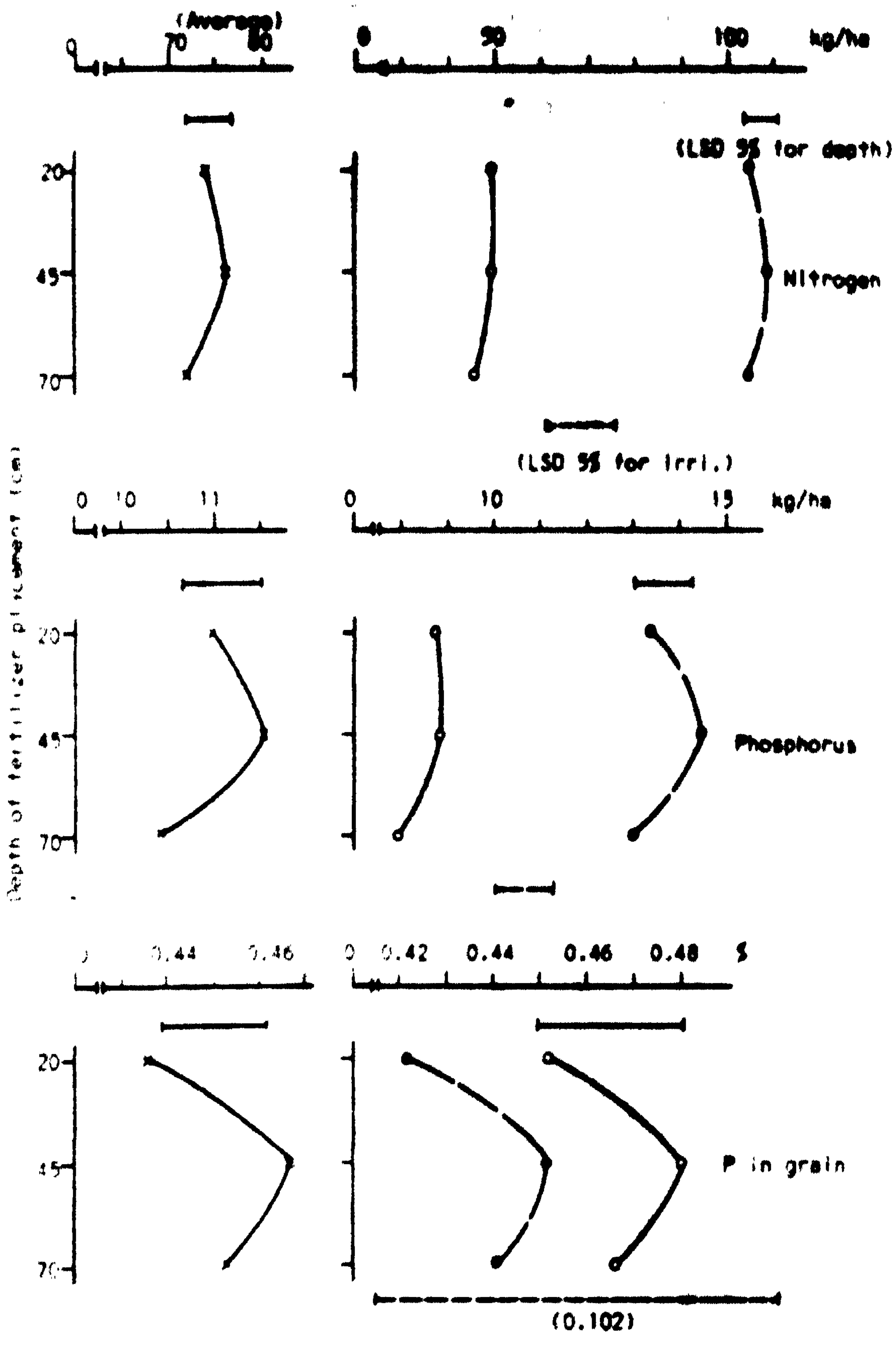


Fig. 7. Changes in nodule growth of chickpea (CPS-1) as affected by N and P placement with and without irrigation

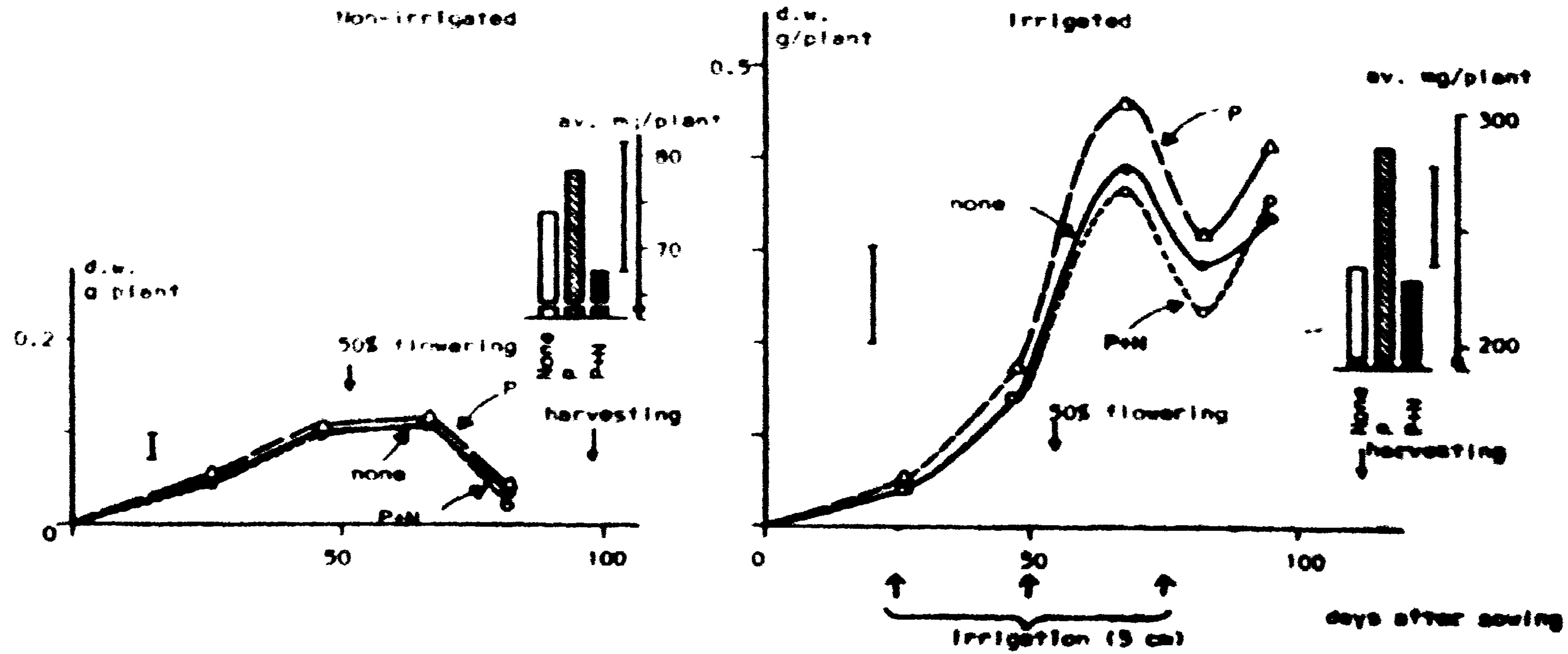


Fig. 8. Changes in total dry matter of [illegible] in response to N and P [illegible] with and without irrigation

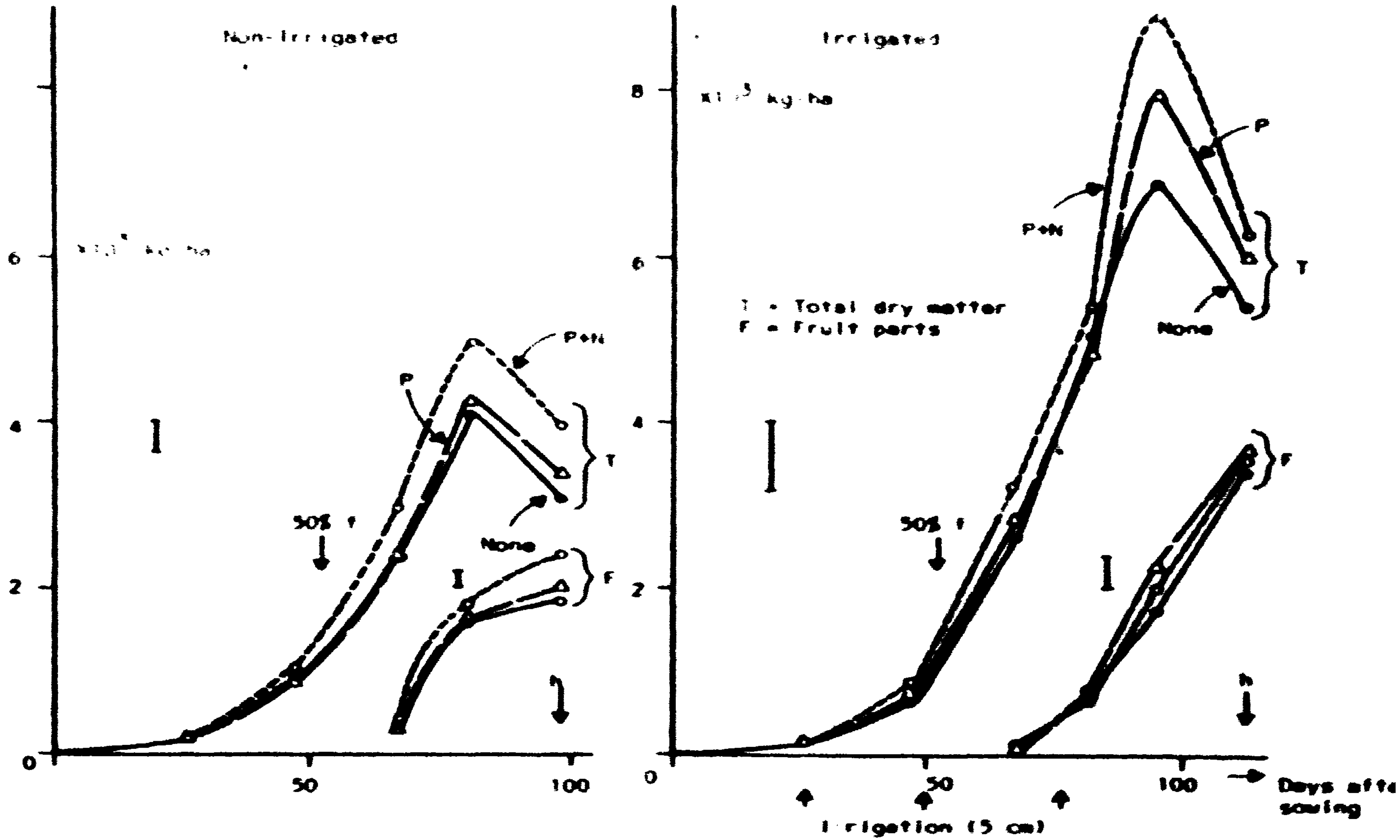


Fig. 9. Changes in N uptake by chickpea with time in response to N and P placement and irrigation

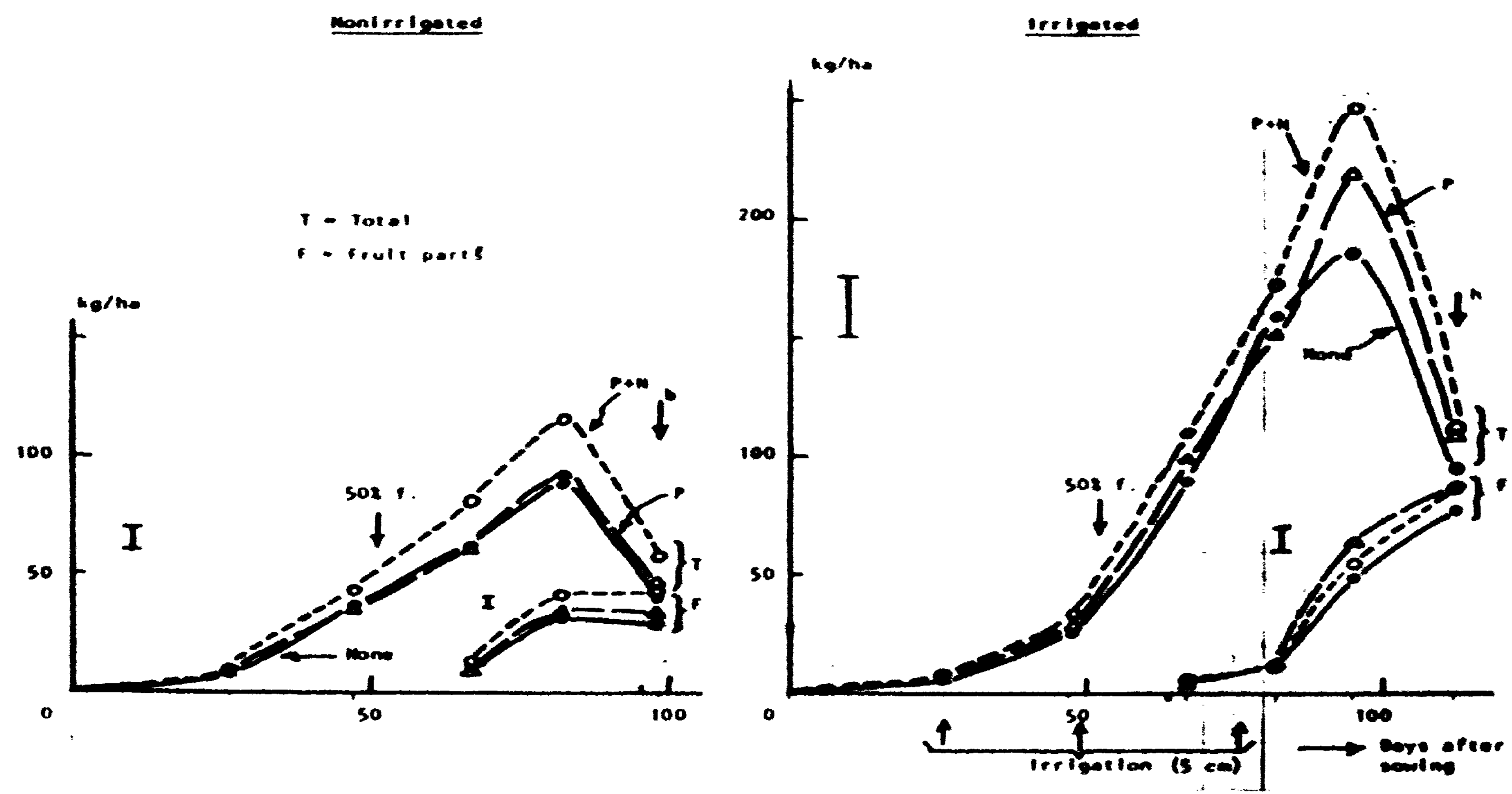


Fig. 10. Changes in P uptake by chickpea with time in response to N and P placement and irrigation

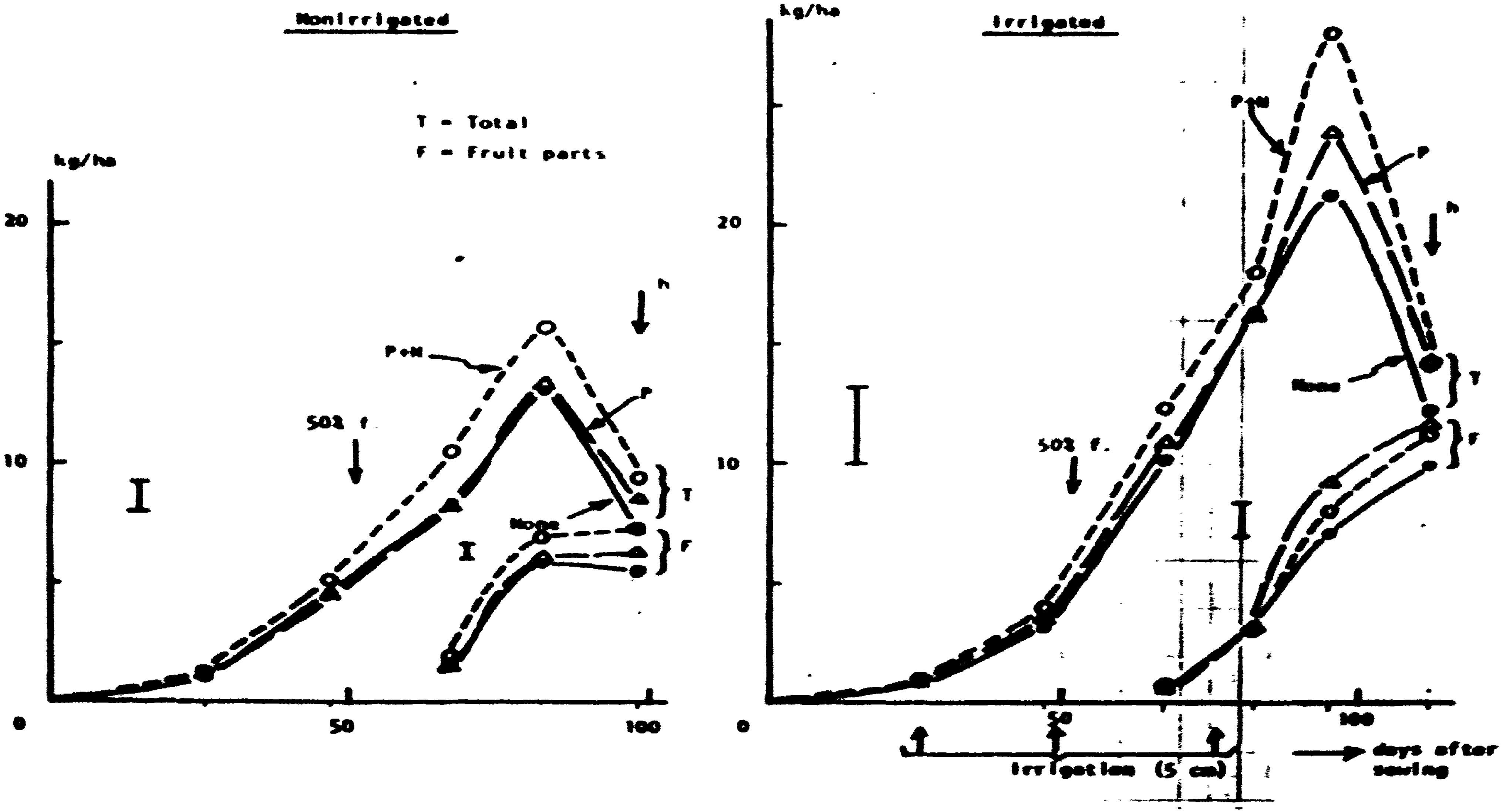


Fig. 11. Changes in dry matter of various components of chickpea with time in irrigated and non-irrigated treatments

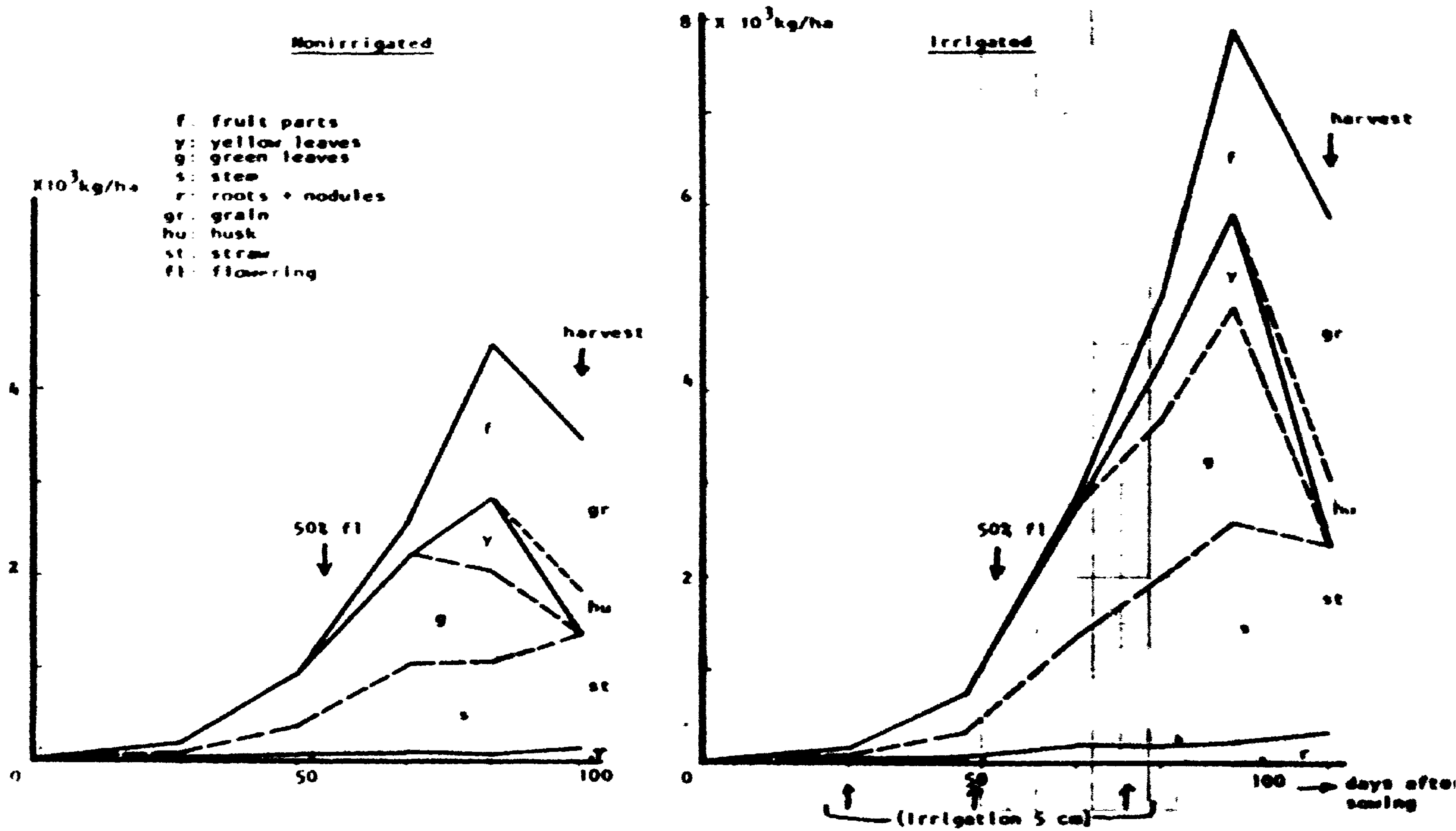


Fig. 12. Changes in N concentrations in parts of chickpea with and without irrigation (% in d.m.)

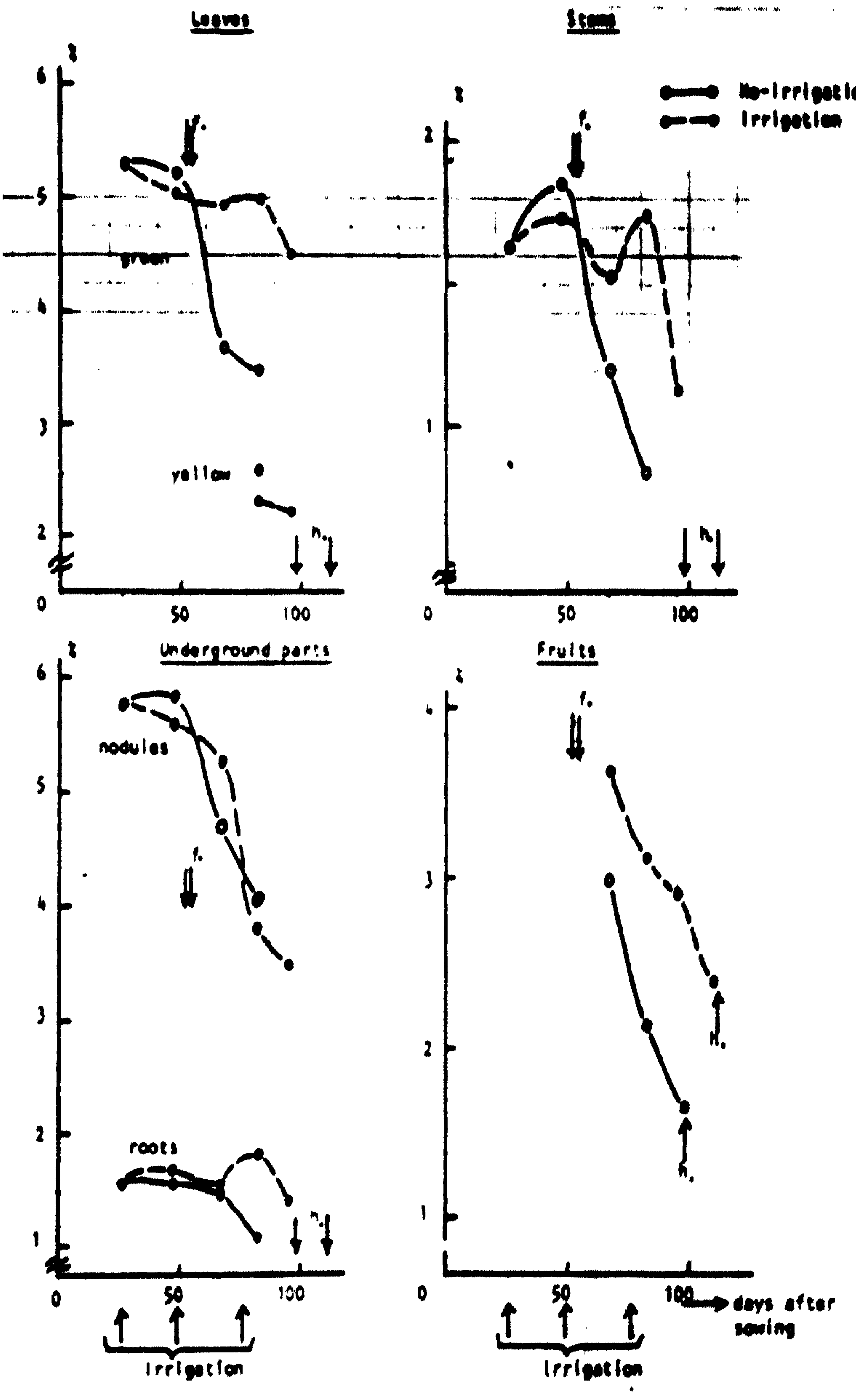


Fig. 13. Changes in P concentrations in component parts of [illegible] with and without irrigation (% in d.m.)

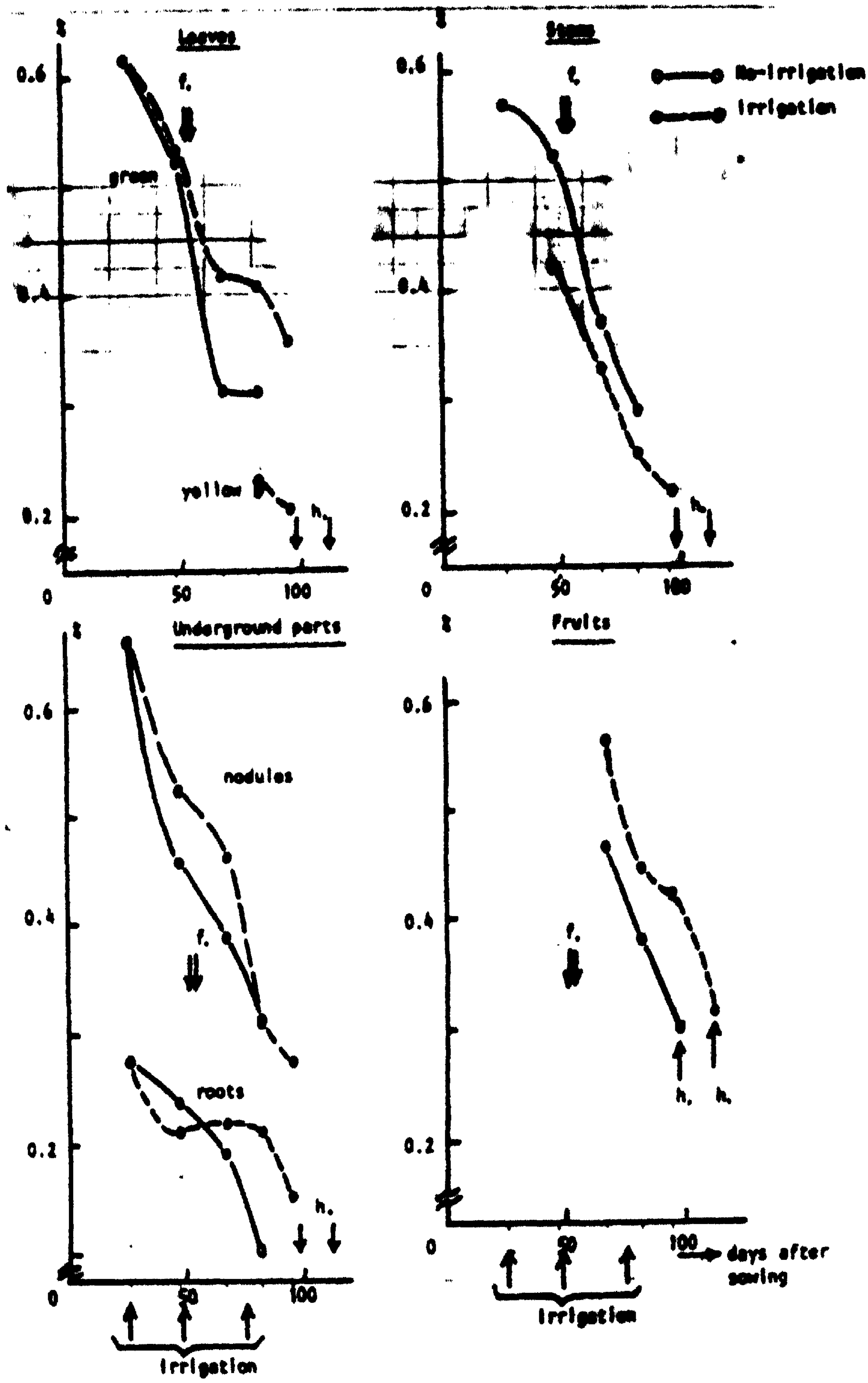


Fig. 14. Changes in N and P concentrations (% of dry matter) in green leaves of chickpea in different fertilizer and irrigation treatments

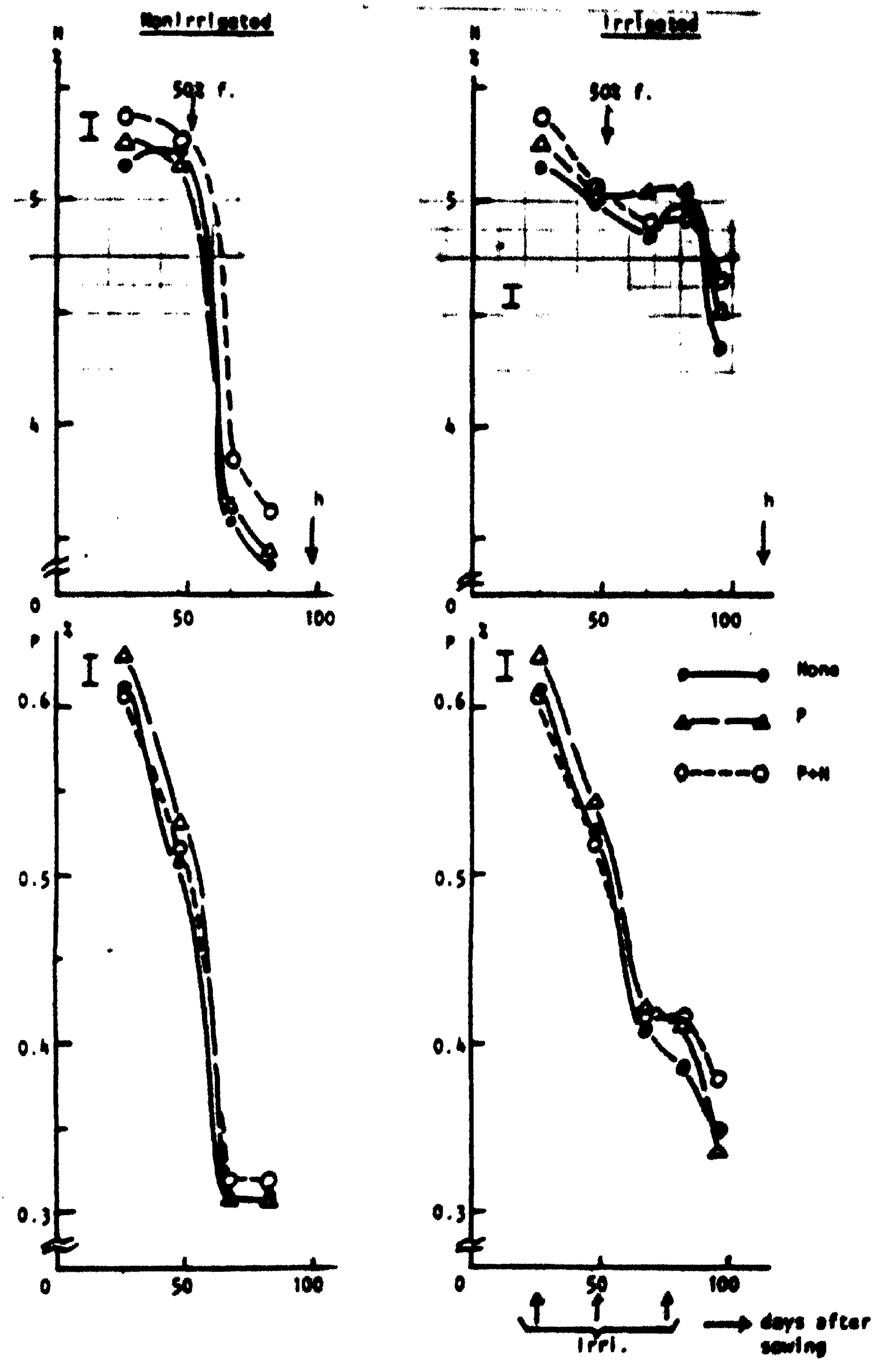


Fig. 15. Changes in the N and P concentrations (% of dry matter) of chickpea fruits in different fertilizer and irrigation treatments

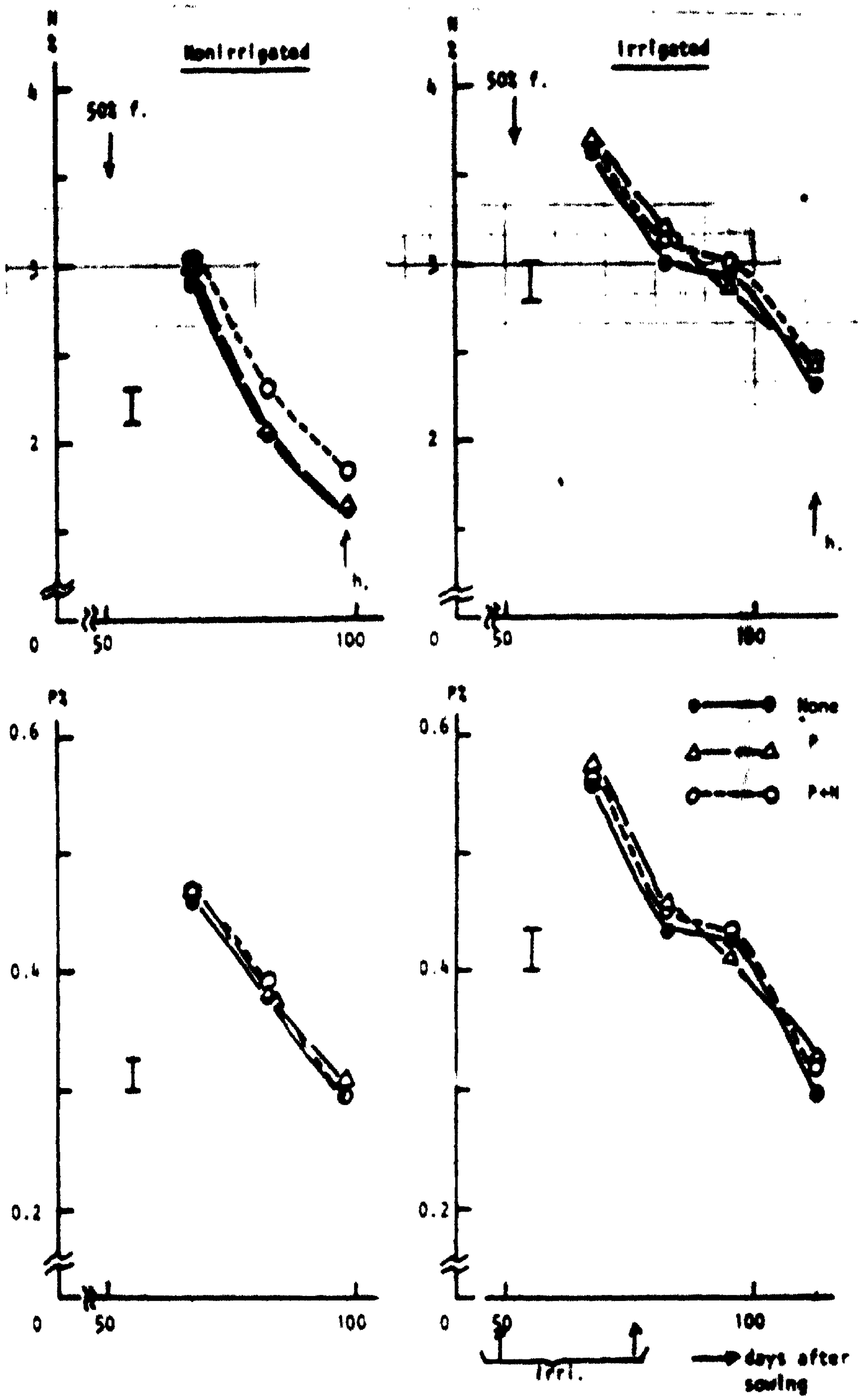


Fig. 16. Changes in N and P concentration (% of dry matter) of chickpea nodules in different fertilizer and irrigation treatments

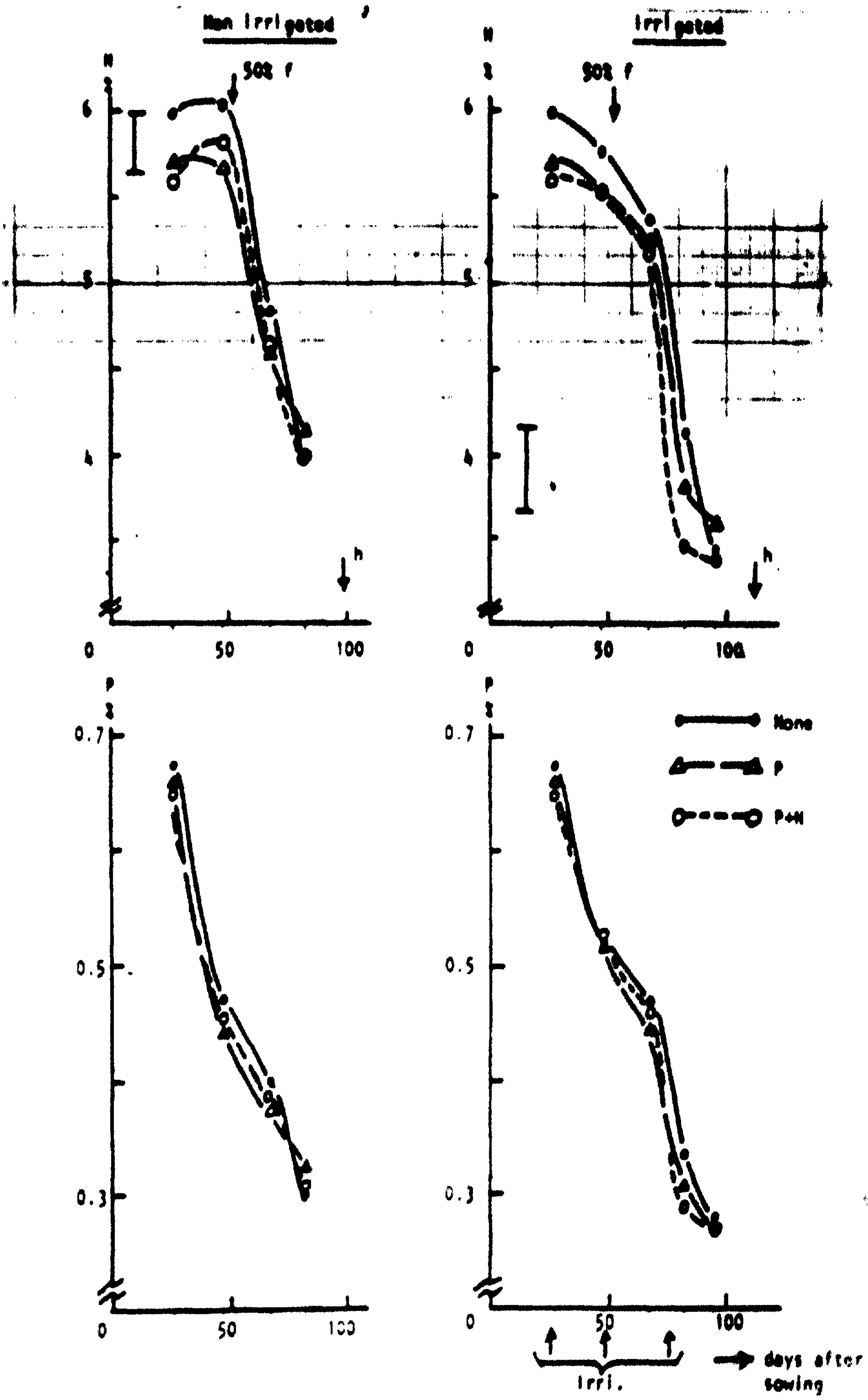


Fig. 17. Response in yield of pigeonpea (BDN-1) to P and N placement with and without irrigation

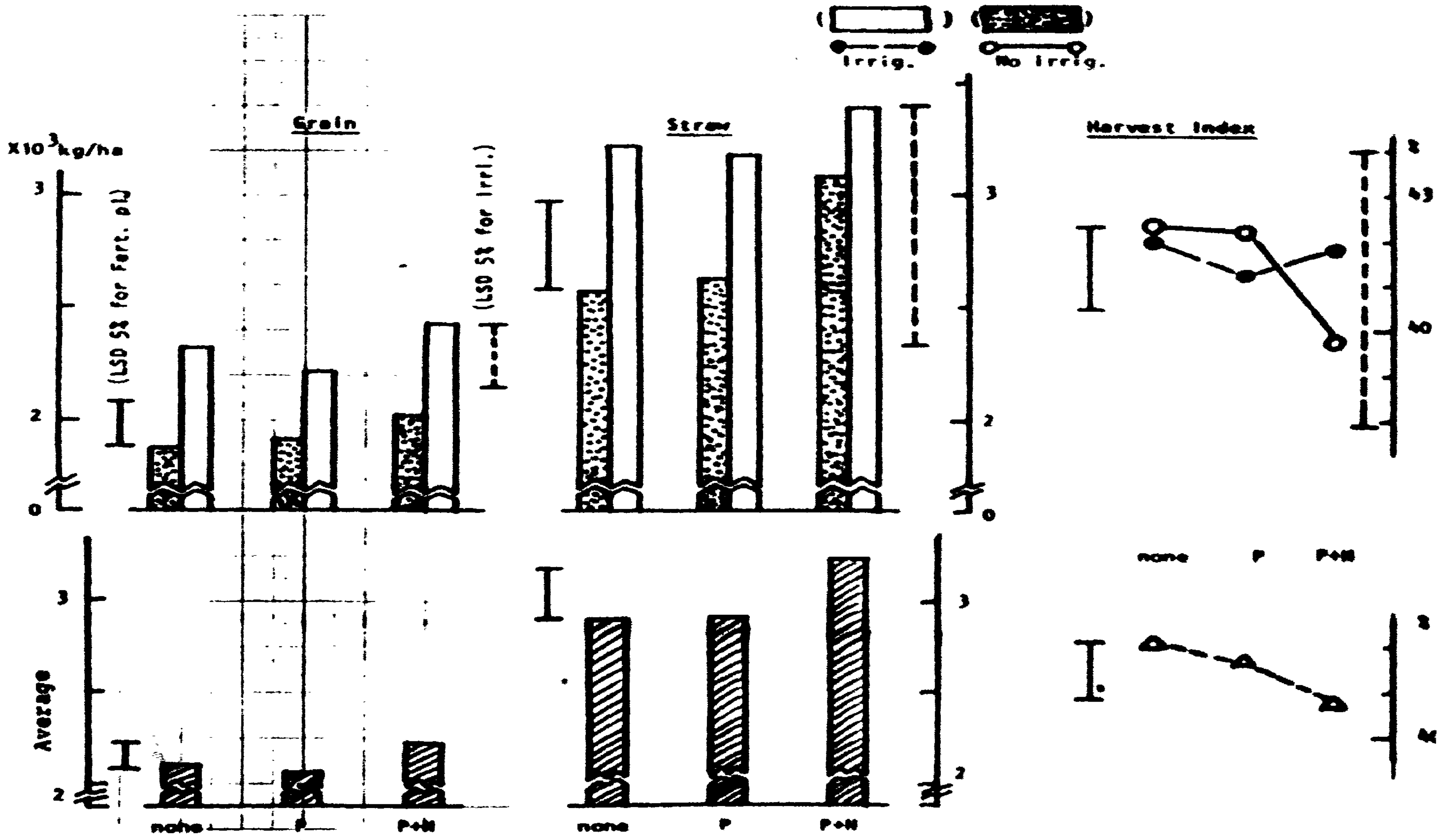


Fig. 18. Total uptake of N and P by pigeonpea at harvest stage with and without irrigation

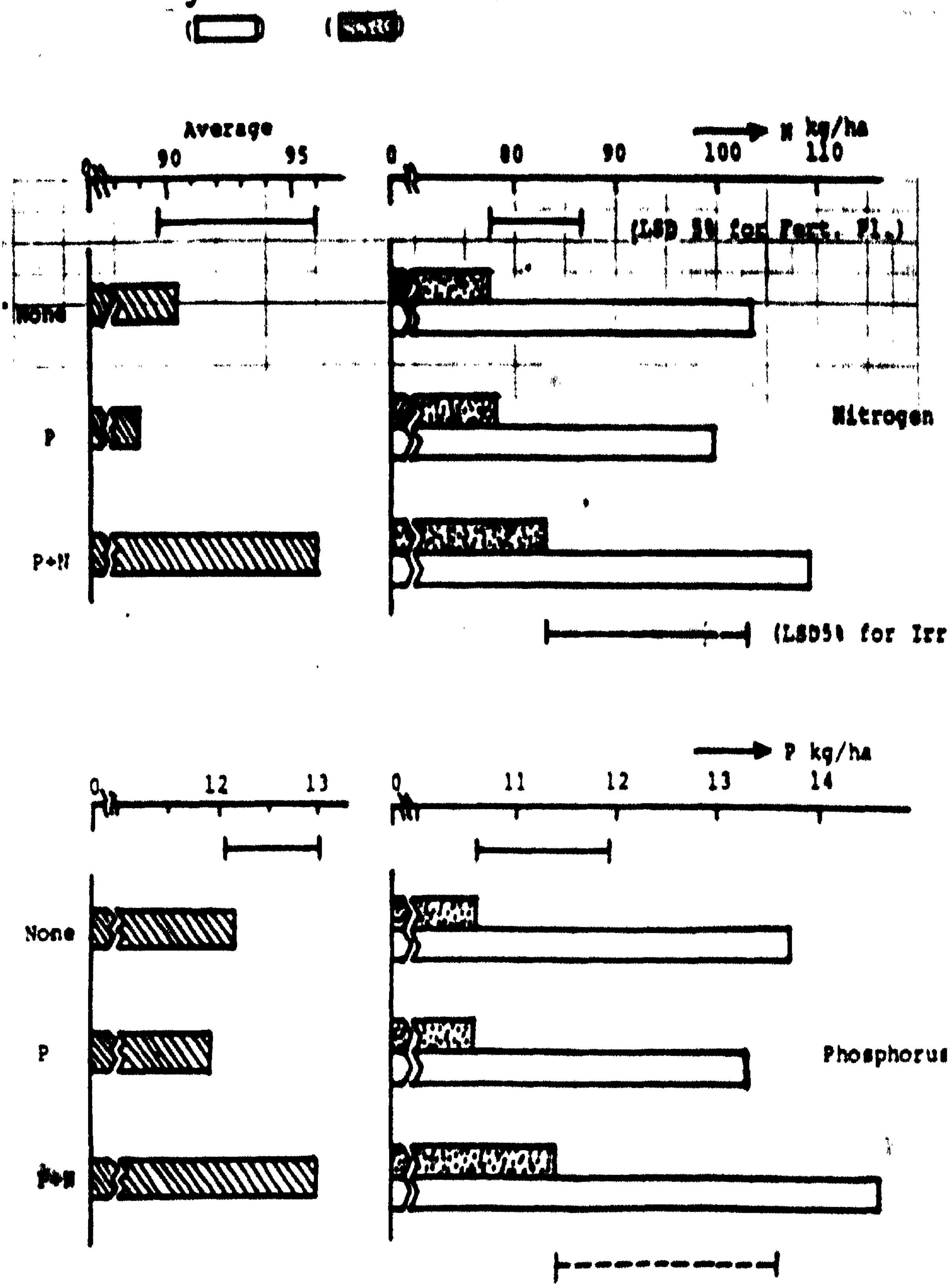


Fig. 19. Responses of pigeonpea grain to P and N placements with and without irrigation

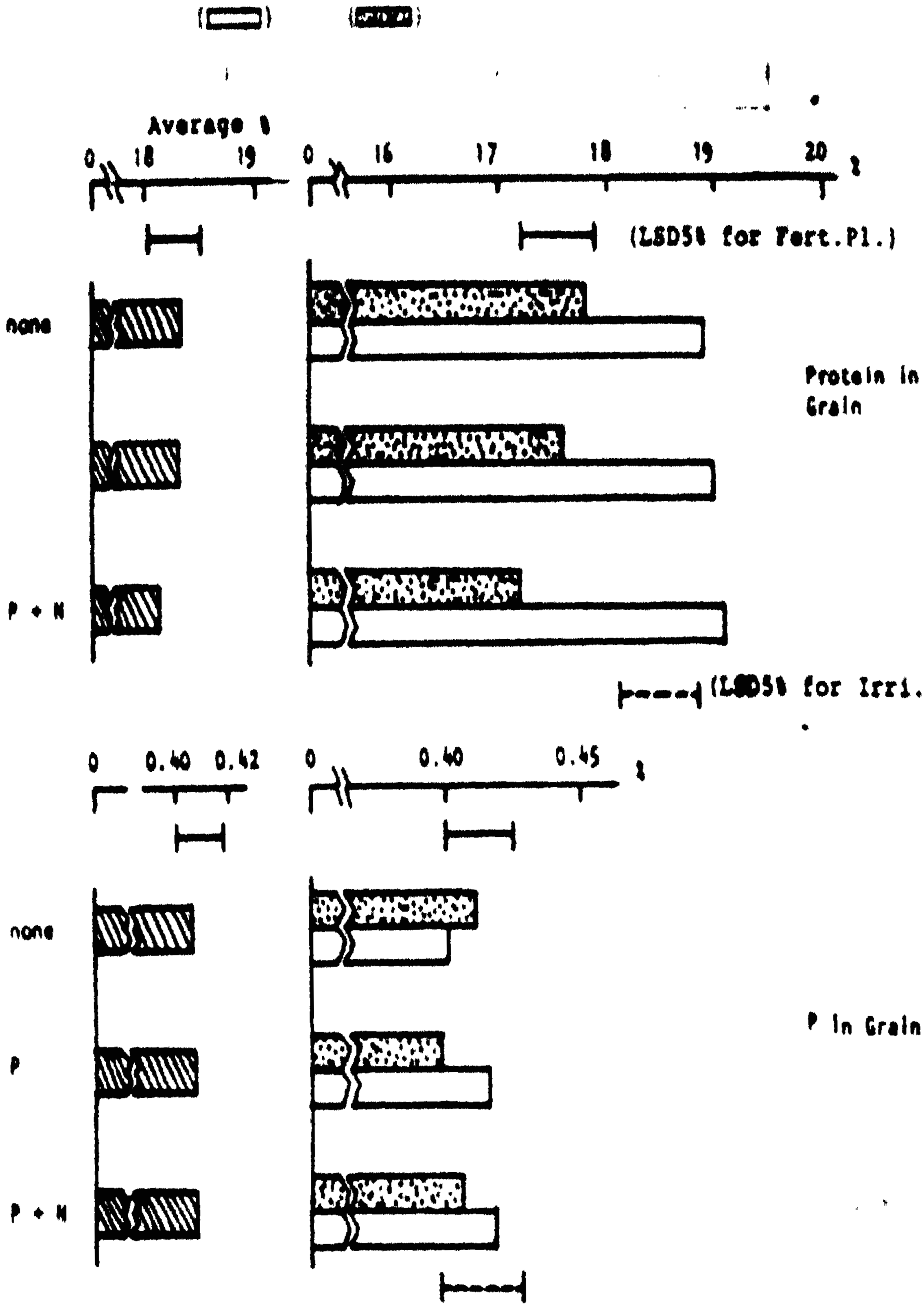


Fig. 20. Changes in dry matter, nitrogen and phosphorus uptake by pigeonpea with and without irrigation

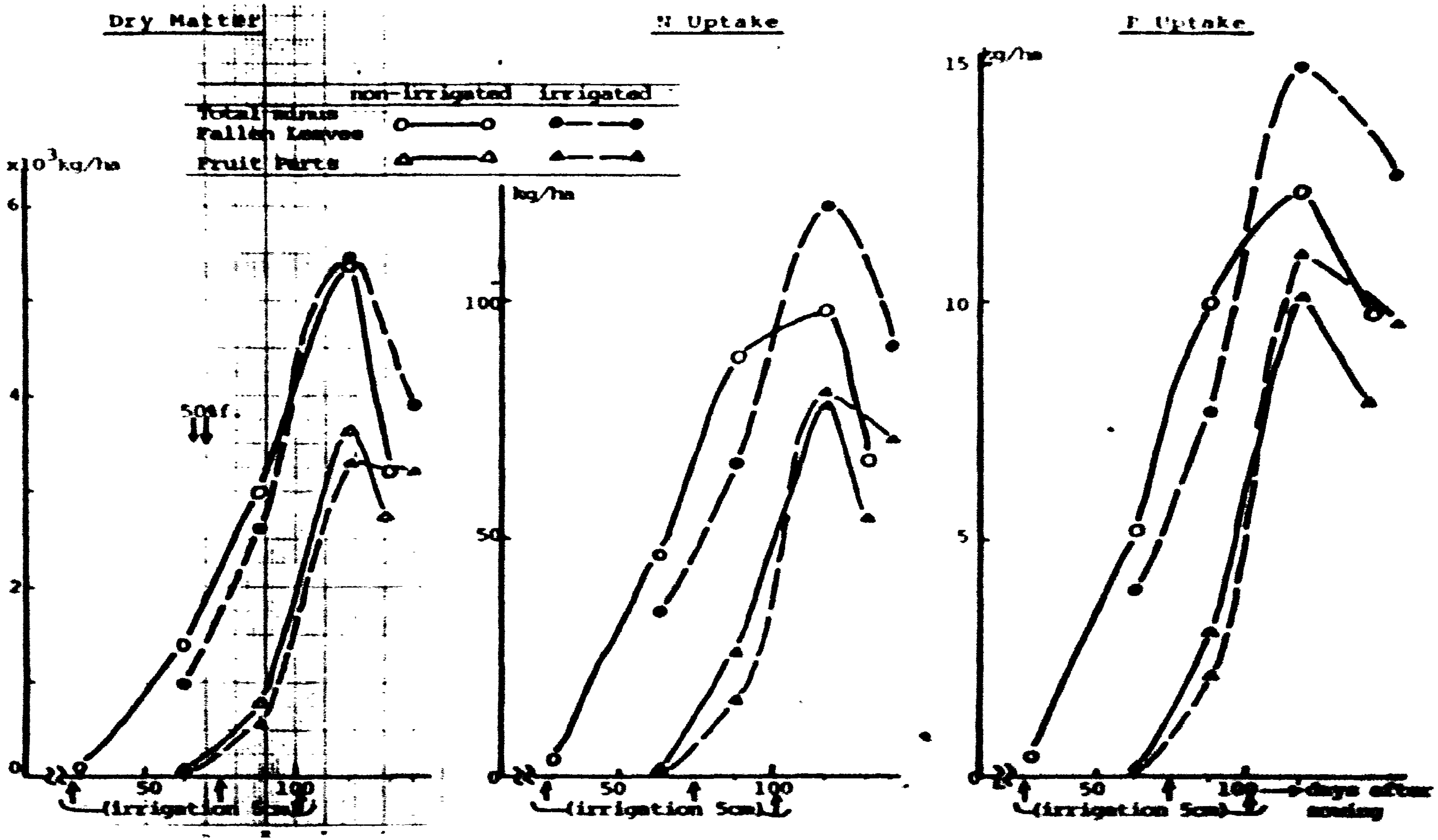


Fig. 21. Changes with time in dry weights of components of pigeonpea

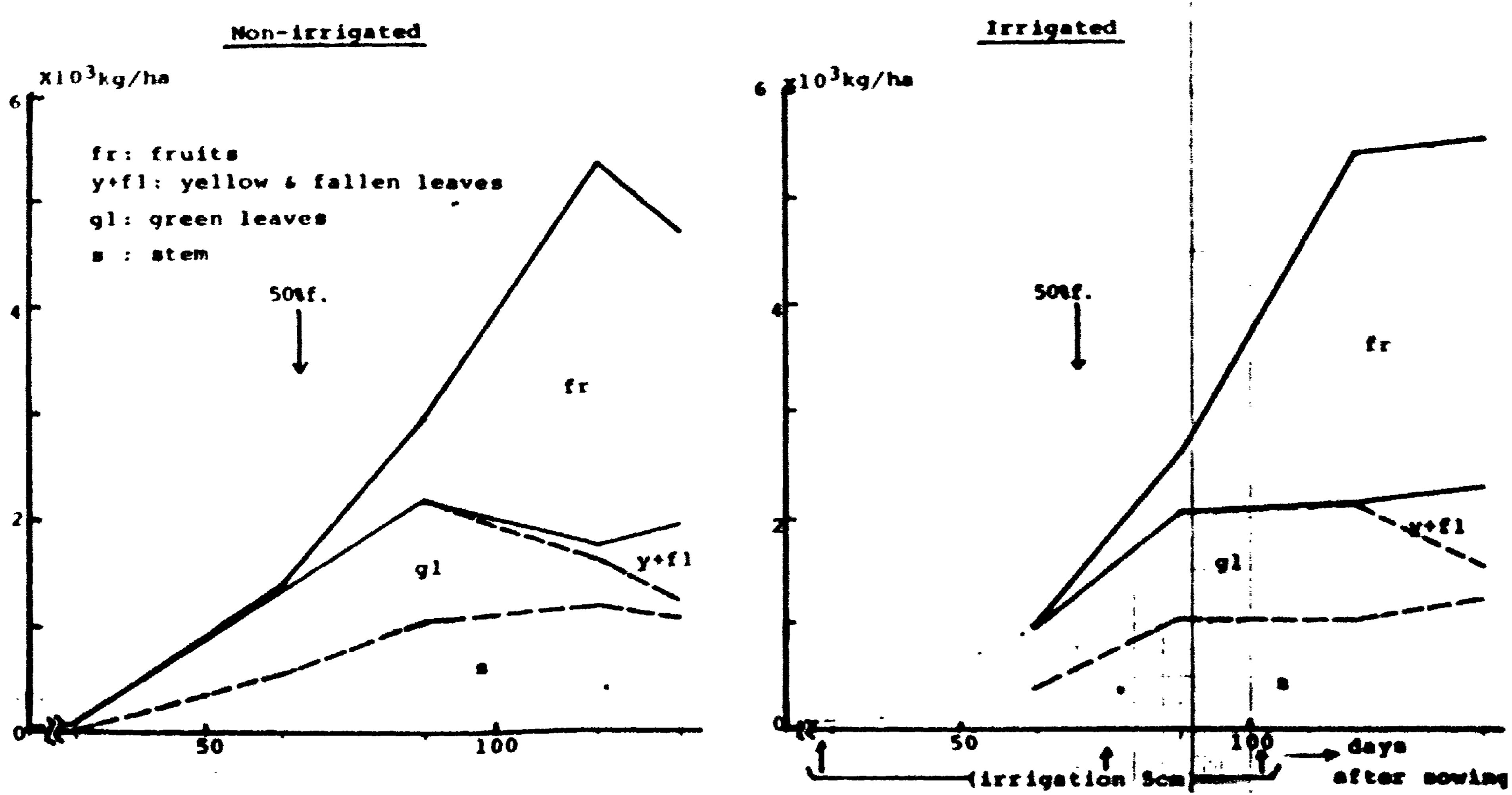


Fig. 22. Dry matter changes in pigeonpea

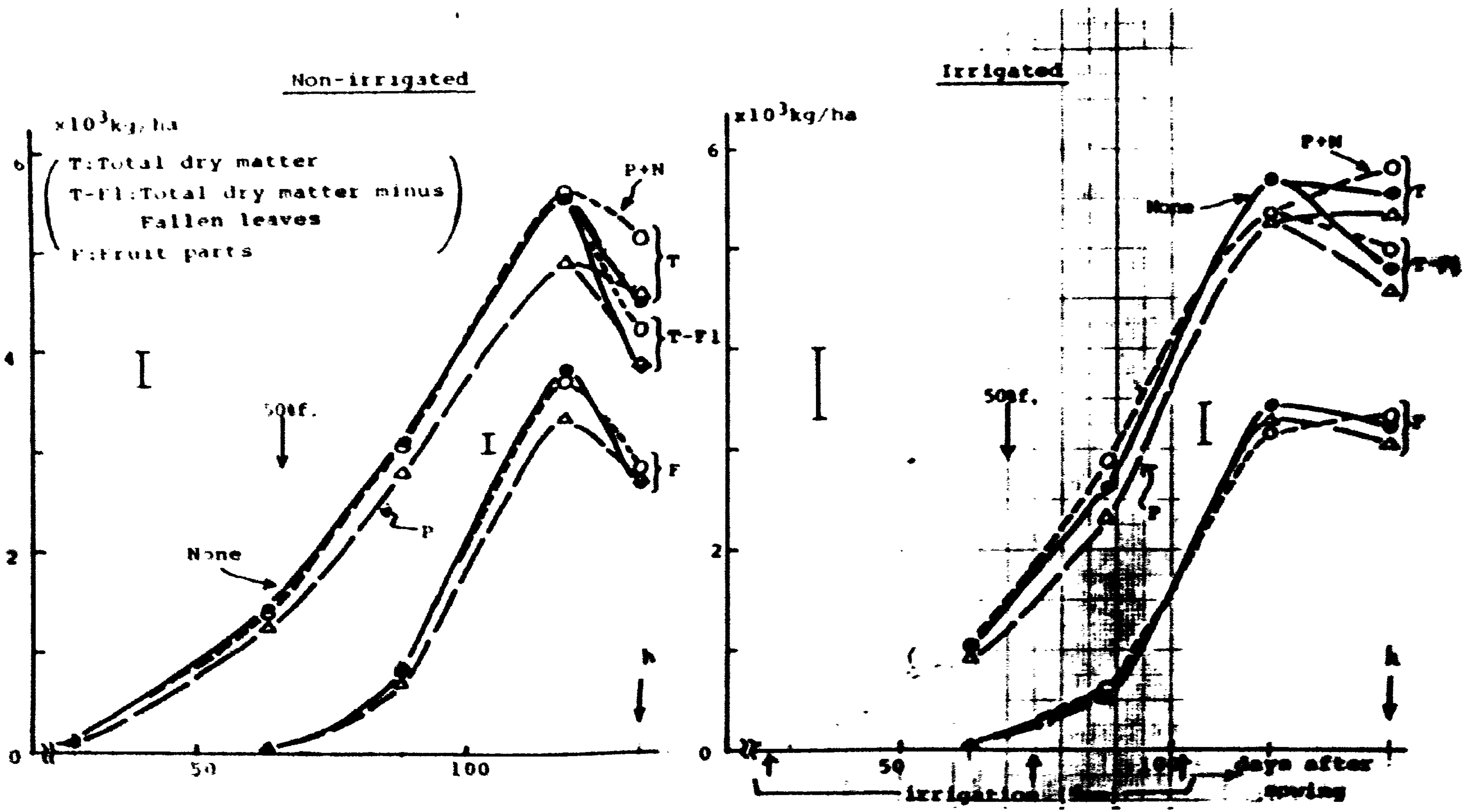


Fig. 23. Changes in nitrogen uptake by pigeonpea

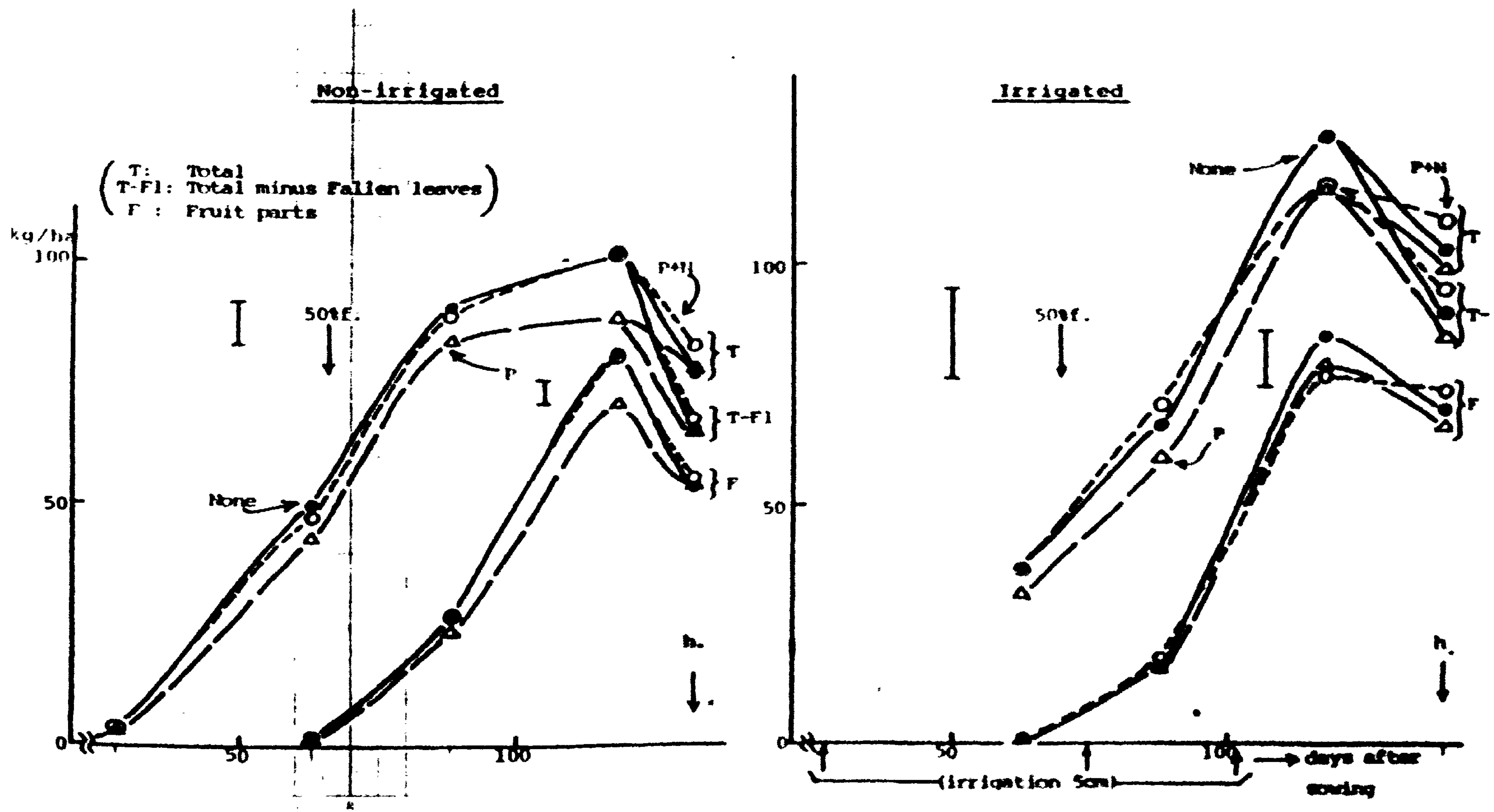


Fig. 24. Changes in phosphorus uptake by pigeonpea

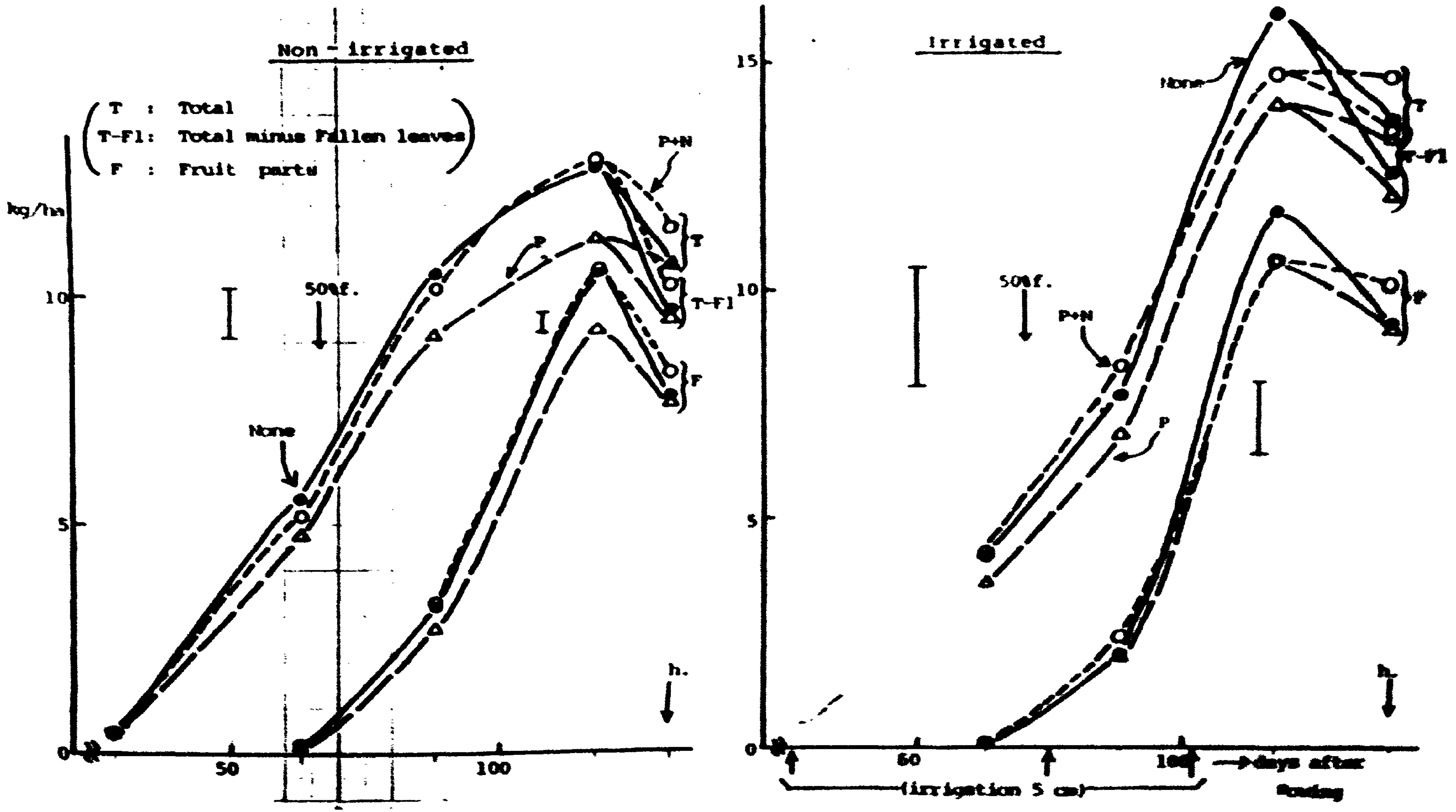


Fig. 25. Changes in nitrogen concentration in various parts of pigeonpea with and without irrigation (% in dry matter)

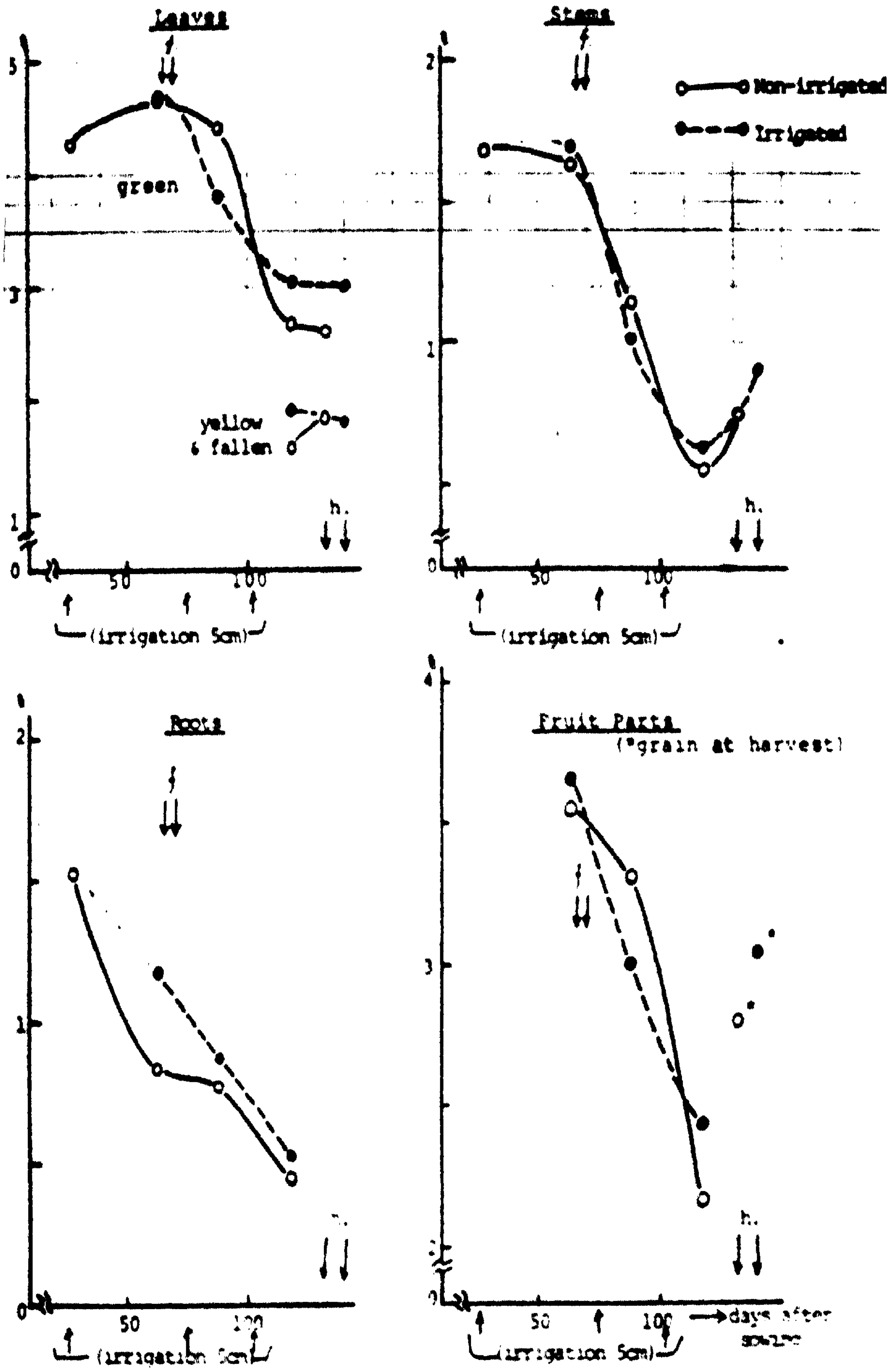


Fig. 25. Changes in phosphorus concentration in various parts of pigeonpea with and without irrigation (% in dry matter)

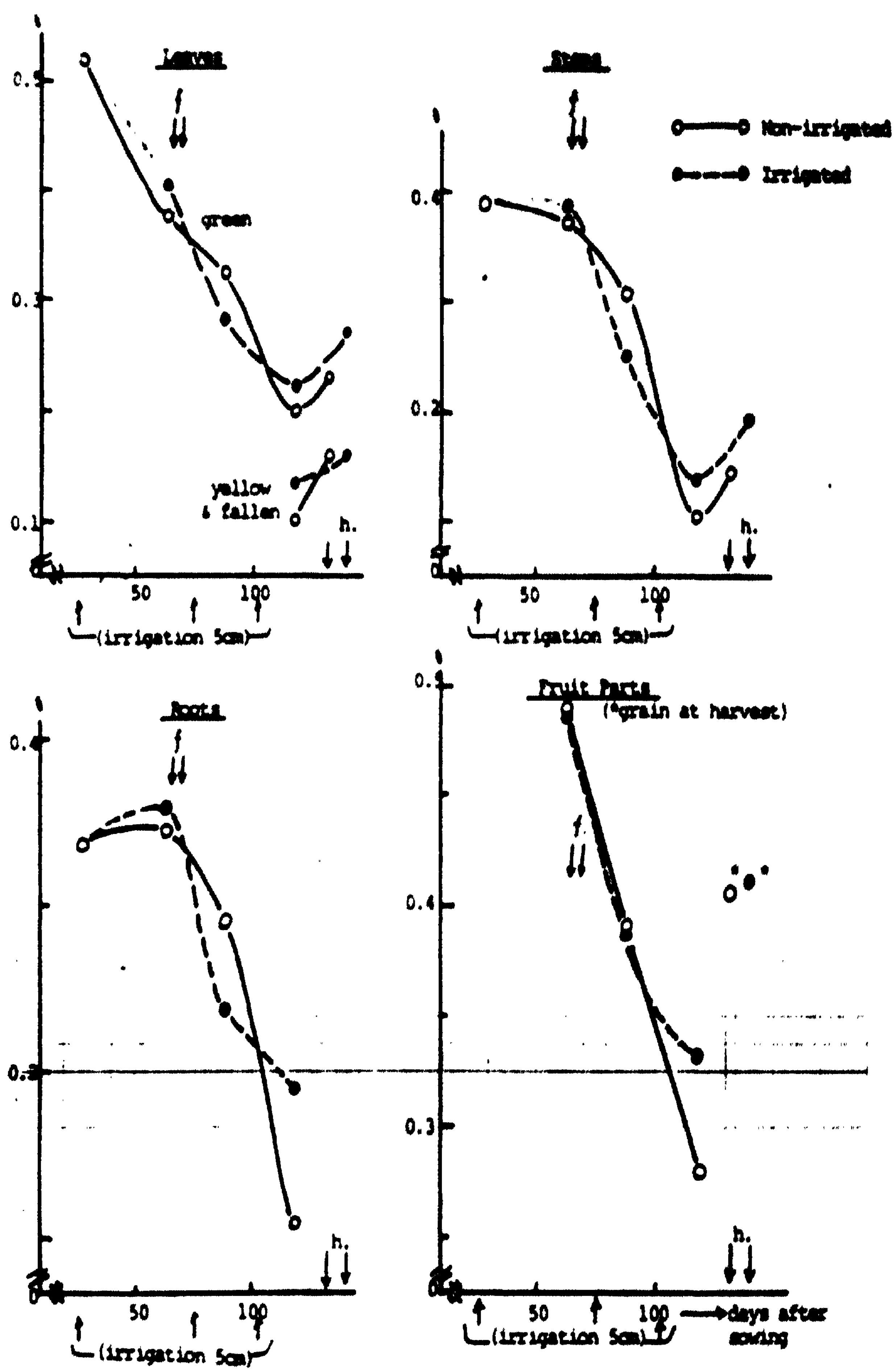


Fig. 27. Effect of depth of fertilizer placement on the intermediate growth and final yield of pigeonpea without irrigation (Total shoots and and fruit parts dry weight kg/ha)

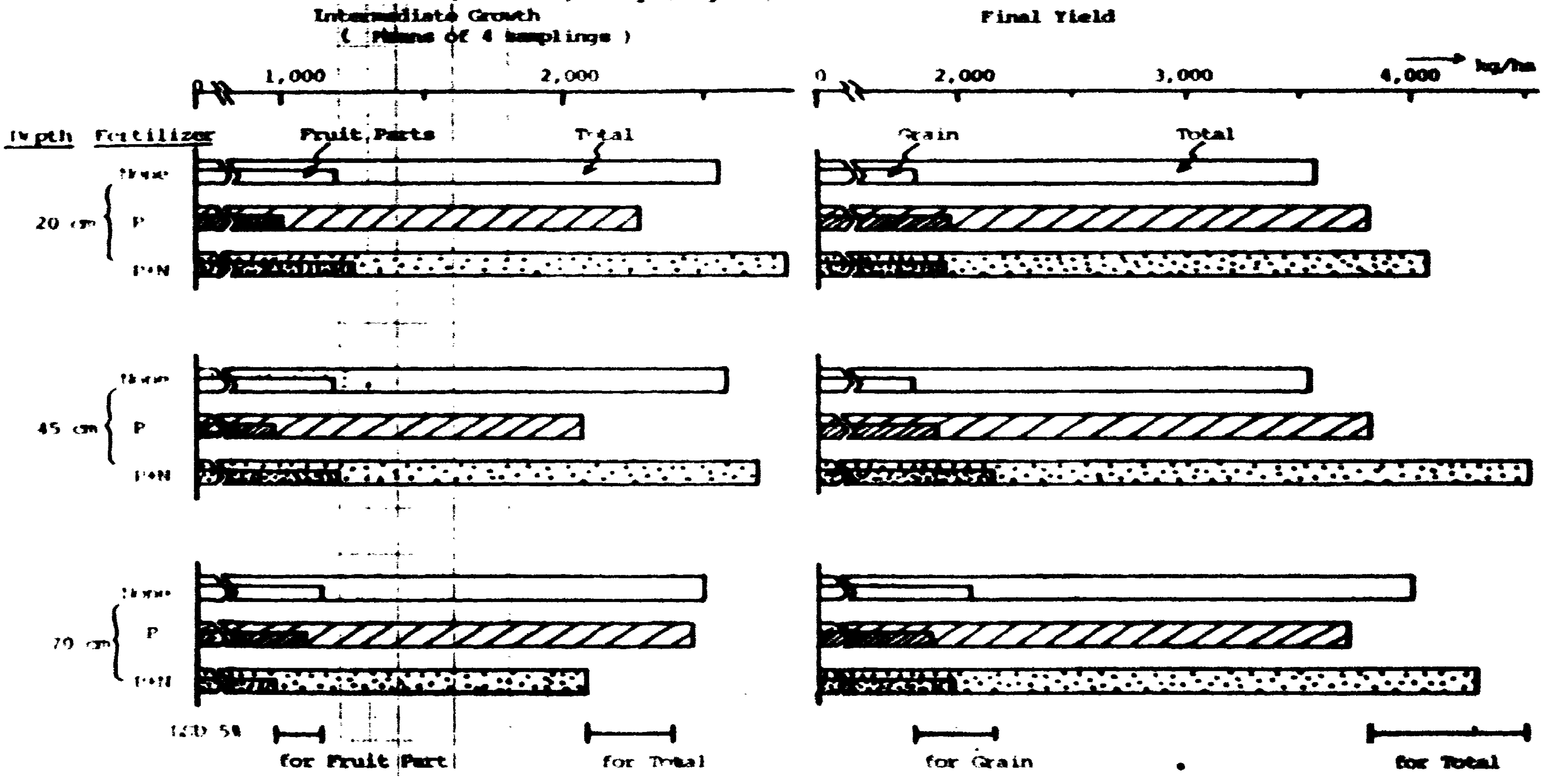


Fig. 28. Changes in N and P concentration of pigeonpea green leaves (% in dry matter)

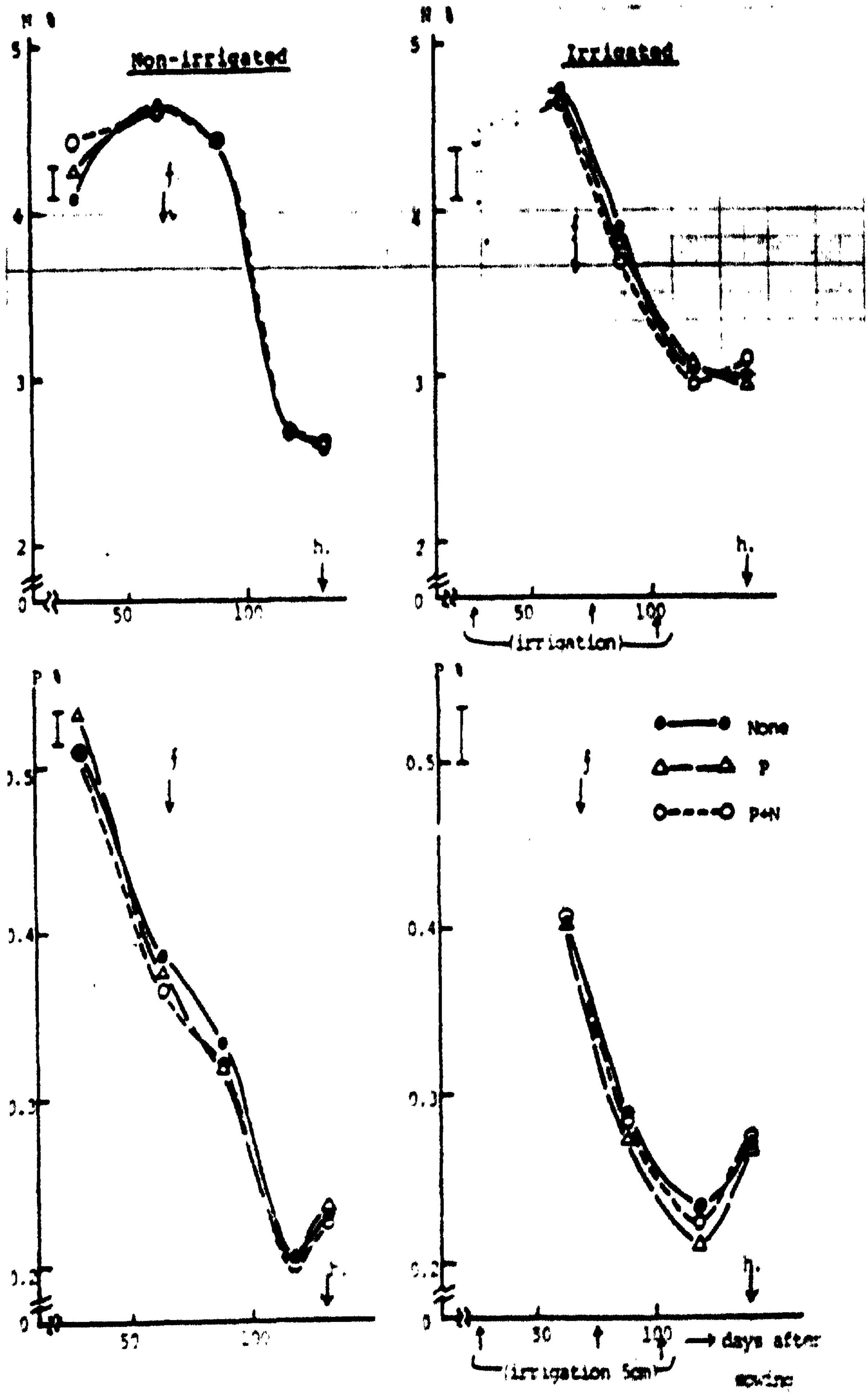


Fig. 29. Changes · N and P concentration of pigeonpea stems
(% in dry matter)

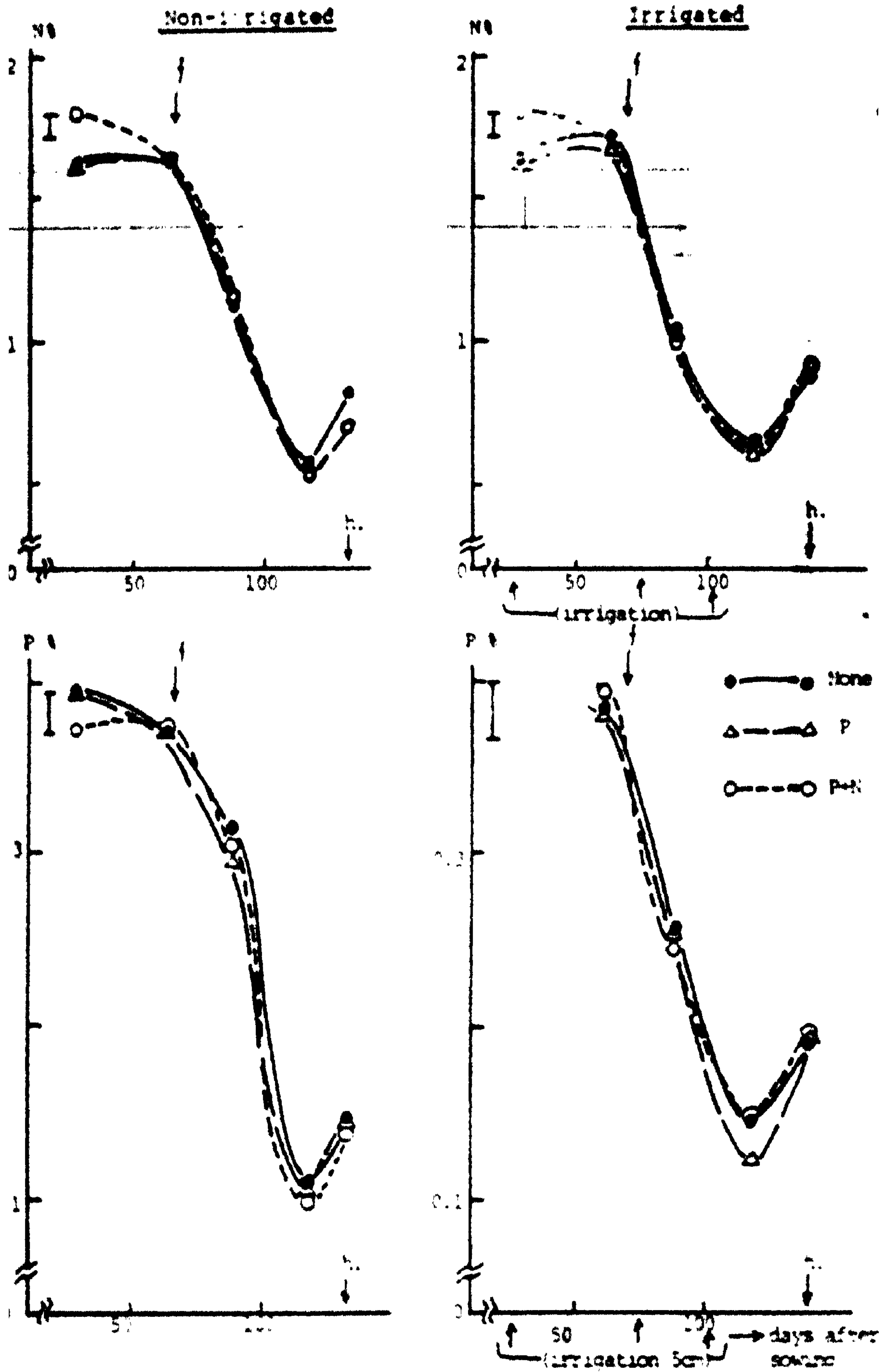
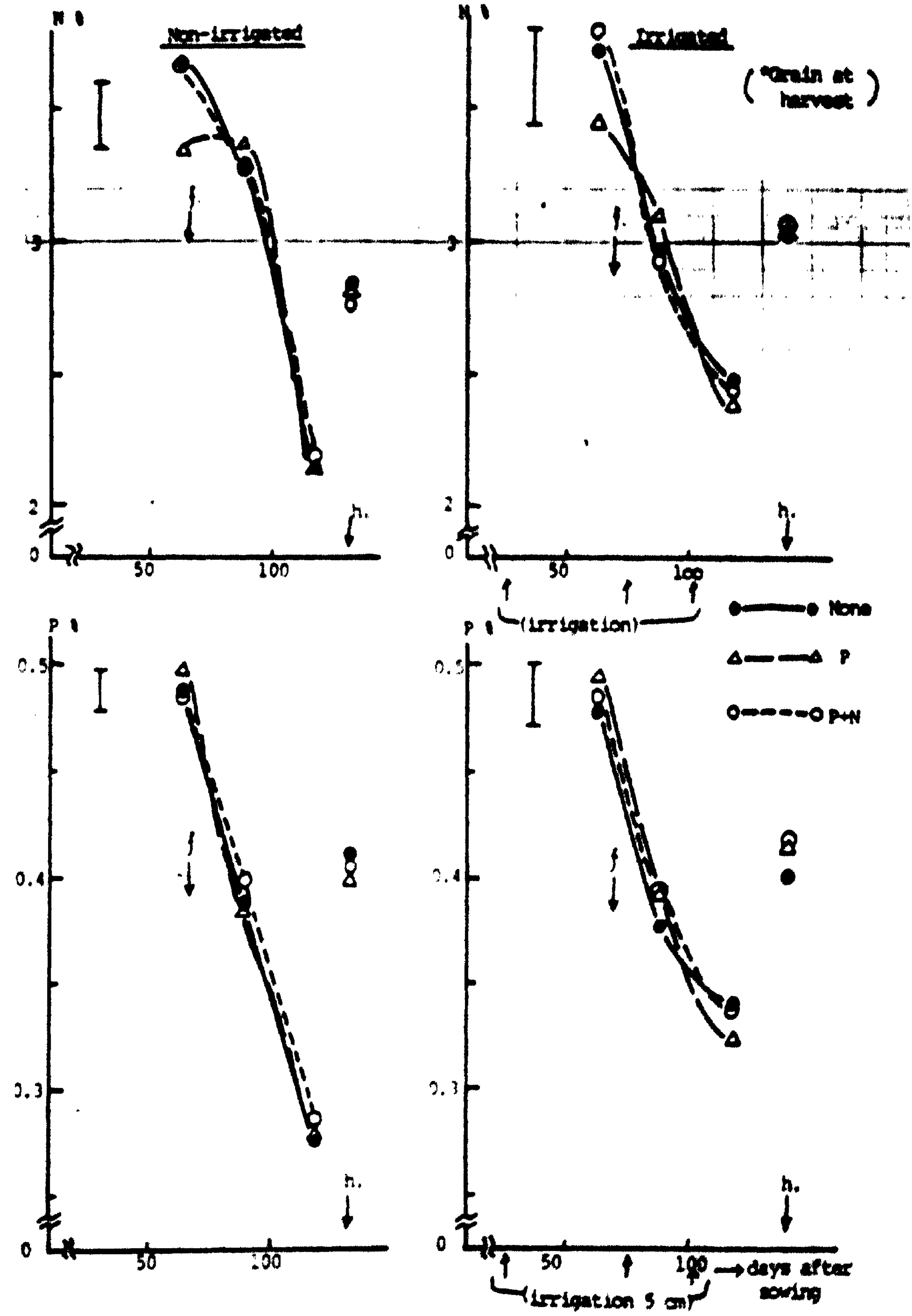


Fig. 30. Changes in N and P concentration of pigeonpea fruit parts (% in dry matter)



PART II

Effect of Phosphatic Fertilizers on Chickpea and Pigeonpea Growth under Different Moisture Conditions in Vertisol in Pots

1. Introduction

The Farming Systems Program at ICRISAT reported that the relative responses to added phosphorus on Vertisol were as follows: Sorghum>Millet>>Pigeonpea (ICRISAT Annual Report 1982, p.253-255). In a pot experiment, they also showed that pigeonpea was much more efficient than sorghum in absorbing P from an Alfisol low in available P (Ibid, 1979/1980, p.184-185).

The objective of this experiment was to observe the responses of chickpea and pigeonpea to phosphatic fertilizers under different moisture levels in pots using a virgin Vertisol.

2. Materials and Methods

Soil

Some chemical properties of virgin Vertisol used in the experiment are shown in Table 1. Eighteen kg of air dried and evenly crushed soil was added to each pot (Polyethylene bucket).

Table 1. Chemical Properties of Soil (ppm dry basis)

PH	EC (mmhos/cm)	Available N	Available P	Exchangeable K	Exchangeable Na	Exchangeable Mg	Available Zn	Available Fe
8.30	0.28	48	0.7	150	237	225	0.54	5.0

Phosphatic fertilizers

Single Superphosphate (SSP),

Fused Magnesium Phosphate (FMP), ... P in FMP is almost insoluble in water and slowly soluble in dilute acid.

No fertilizers except P were added.

P fertilizer (140 mg P/pot) was band placed as a powder at 17 cm and 19 cm depth for chickpea and pigeonpea, respectively.

The amount of P applied nearly corresponds to 20 kg/ha.

Moisture treatment

Three levels of soil moisture content were maintained by weight; namely 27% (field capacity), 23% (middle) and 19% (just above wilting point). In order to keep these levels throughout the experimental period, deionized water was sprayed on the surface of the soil in each pot every two days.

Plant cultivation

The two pulses were cultivated as follows,

	Chickpea	Pigeonpea
Cultivars	CPS-1	ICP-1-6
Sowing	on 7 Aug 1980, 9 seeds/pot, 7 cm depth with liquid inoculation,	on 20 Aug 1980, 9 seeds/pot, 3 cm depth with seed inoculation.
Thinning	on 18-20 Aug. to 4 plants/pot,	on 28 Aug. to 4 plants/pot.
Harvesting	on 5 Nov 1980	intermediate; 2 plants on 27 Nov 1980; Final; 2 plants on 3 Feb 1981.

Three replications of treatments were kept in the screenhouse and/or glass house during the growth period. Moisture stress severely decreased the growth of both pulses.

3. Results and Discussion

Chickpea

As shown in Fig. 1, chickpea responded well to P application with increasing moisture in the soil, resulting in about three times higher grain yield as well as total dry matter of shoot at field capacity (27%).

Contrary to shoot and grain weight, root dry weight was less affected by moisture level in the soil. SSP stimulated root growth even under moisture stress (19%).

FMP which is solubilized only under acidic condition in the soil, [illegible] fairly effective for growth and yield [illegible] level of field capacity. This result means that [illegible] under alkaline condition of soil, provided that the moisture is kept optimum.

Hundred seeds weight increased linearly with the moisture regime in soils where no P was added, whereas the maximum was observed at 23% moisture level in soils where P was applied (Fig. 2).

Total P uptake by chickpea almost paralleled the growth pattern of shoots. P uptake [illegible] and N was also absorbed in proportion to P uptake. This may be mainly attributed to N2 fixation activity of nodules (Fig. 3).

The P concentration in the grain obviously increased with P application, especially at field capacity (27%). On the contrary, N% in grain decreased with P application. Thus, a clear negative relationship was observed in P and N (protein assumed as N% x 6.25) contents in grain, although the reason for this is not yet known (Fig. 4 & 5).

The absorption rate of P, calculated from the differences in pots between application of fertilizers and control, is shown in Fig. 6. More than 10% of SSP-P was absorbed at field capacity.

Pigeonpea

Pigeonpea also responded well to P application, as was the case for chickpea (Fig. 7). Even under moisture stress, such as at 19% and 23%, SSP and FMP increased grain yield more than twice, respectively. Root growth paralleled shoot growth.

In the case of pigeonpea, shoots of two plants were cut from each pot as intermediate samples at the stage of flower initiation. During pod formation, namely from flower initiation to final harvest, 60 days, total dry-matter increased almost twice in average, irrespective of treatments, whereas, P content of the plant increased more than three times (Fig. 8). In contrast to the results of field trials (1,2), P concentration in green leaves increased markedly during pod formation (Fig. 9). Namely, P absorption was clearly accelerated after flower initiation, resulting in increased N uptake. Percentage of P and N in leaves at flower initiation might have been marginal for deficiency (3), indicating that during the vegetative period (more than 3 months) pigeonpea could only absorb P at about the critical level in proportion to the increase in growth in the pot experiment. After flower initiation, P of SSP was absorbed fairly well even under severe moisture stress condition (19%), whereas P of FMP was absorbed well when soil moisture was kept at 23 and 27%.

In contrast to the results with chickpea, FMP brought about a fairly good grain yield under medium stress conditions of soil moisture (23%) as shown in Fig. 7. This means that pigeonpea, having a relatively longer growth duration, may be able to extract P from scarcely soluble P compounds such as FMP more efficiently than chickpea, especially at later growth stages.

P % in grain was increased with the application of SSP irrespective of soil moisture level, however, with FMP the increase was observed only with 27% moisture in soil (Fig. 10). Unlike the case of chickpea, there was no relationship between P% and N% in grain.

As indicated in Fig. 11, more than 20% of SSP-P applied was totally absorbed at field capacity (27%).

Summary

Responses of chickpeas and pigeonpeas to single super phosphate (SSP) and fused magnesium phosphate (FMP) under three levels of soil moisture - 19%, just above wilting; 23%, medium; 27%, field capacity, by weight - in pot condition using virgin Vertisol were studied.

Both pulses responded well to P application as soil moisture level increased, resulting in a three-fold increase in grain yield at field capacity (27%).

P and N absorption were also considerably affected by application of phosphatic fertilizers and the level of soil moisture.

Pigeonpeas seemed to have a greater ability than chickpeas to absorb P from scarcely soluble P compounds under low moisture conditions.

4. References

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2. Sheldrake, A.R. & Narayanan, A. 1979. Growth, development and nutrient uptake in pigeonpea, Jour. Agric. Sci., 92, 513-526.

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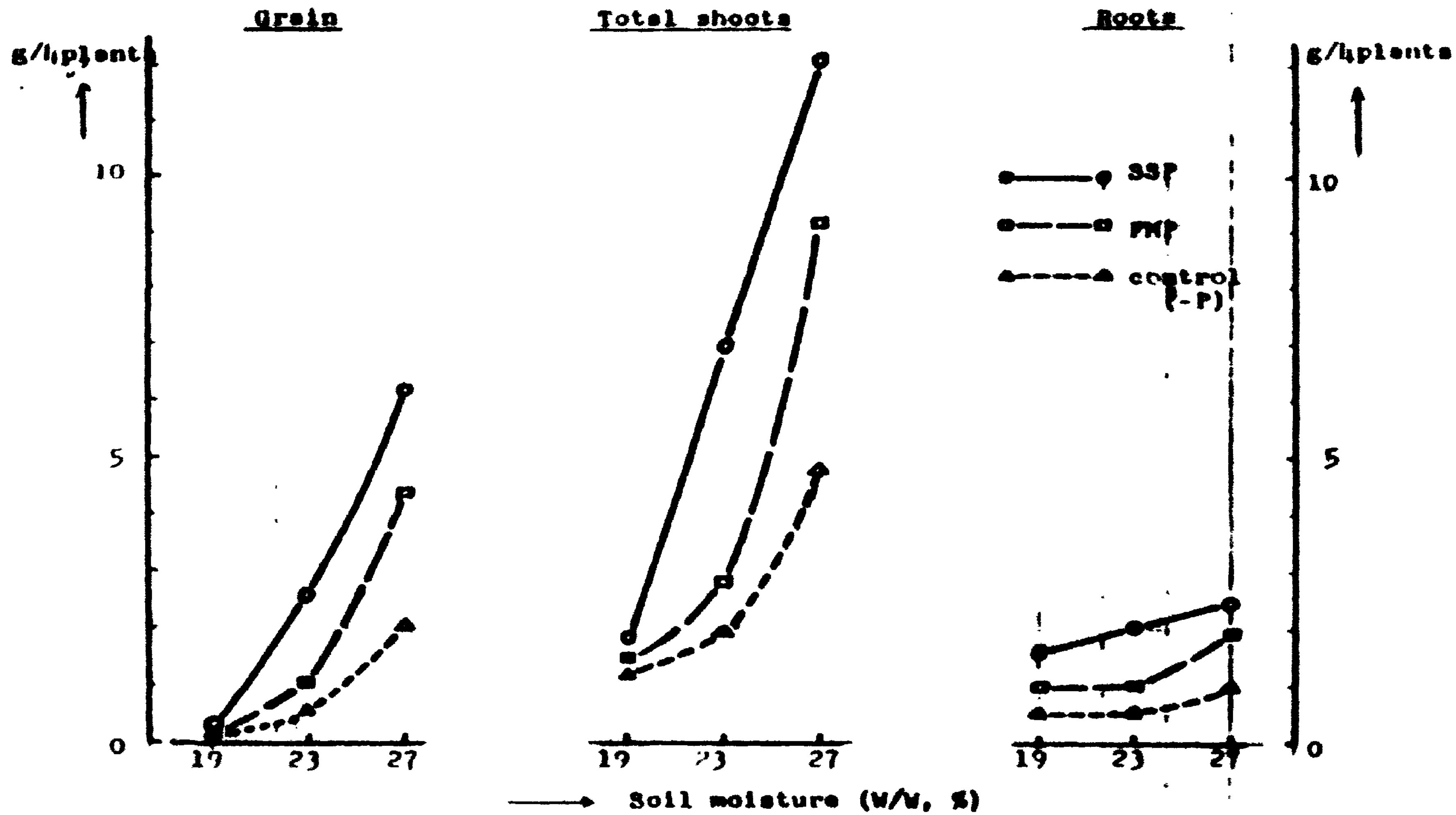

Figure 1, Effect of phosphatic fertilizers on yield and growth under three levels of soil moisture (Chickpea)

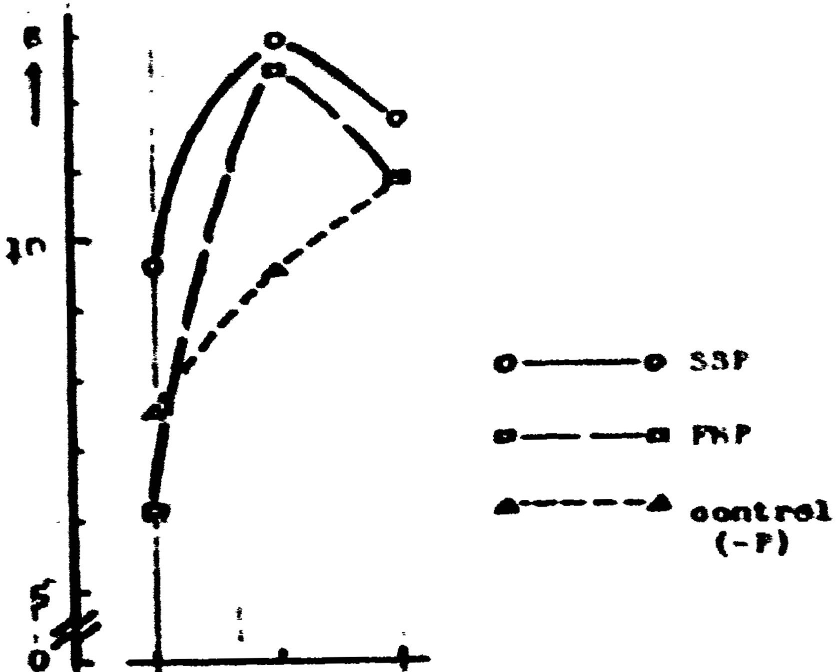

Figure 2, 100 seeds weight
(Chickpea)

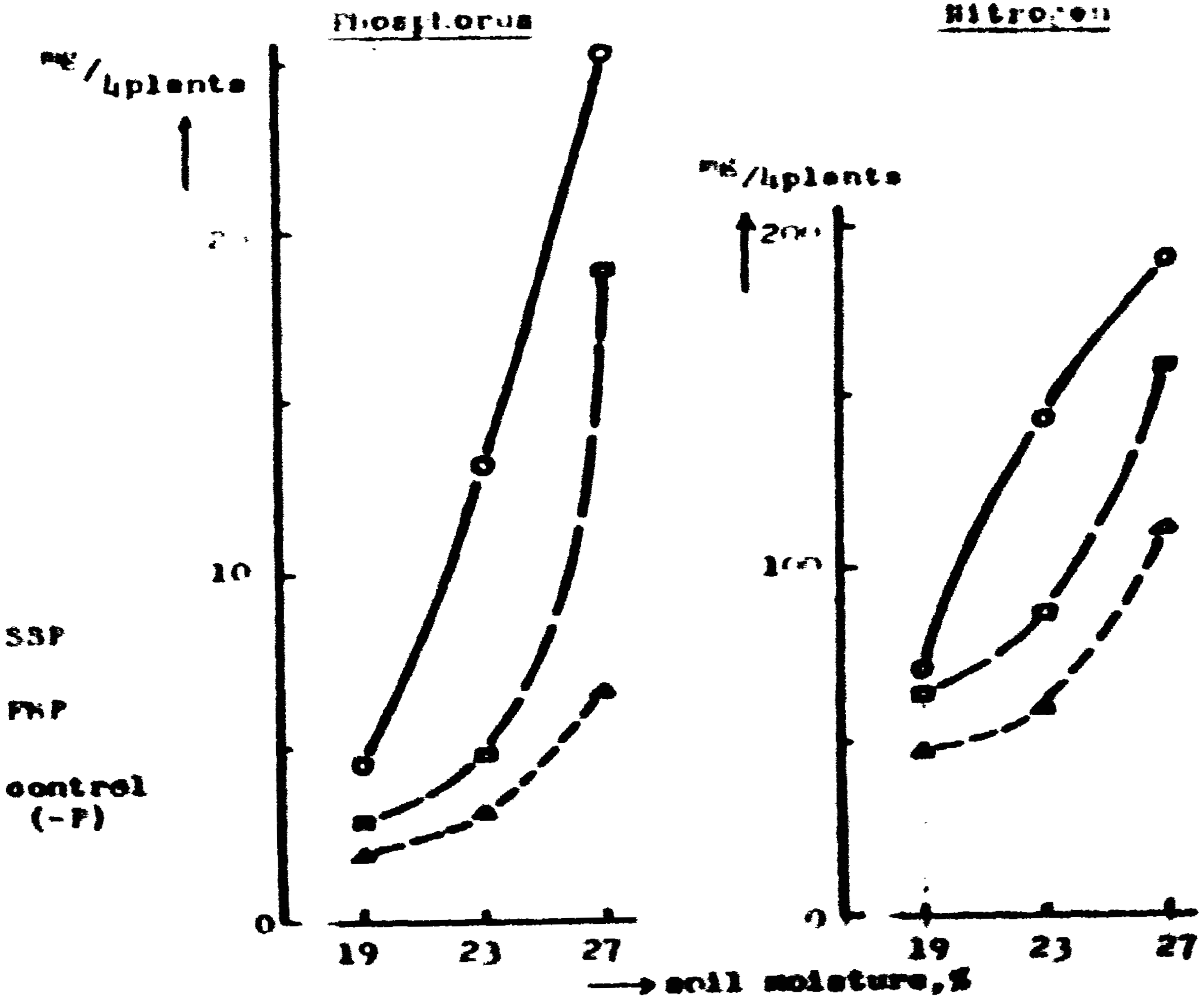

Figure 3, Phosphorus and Nitrogen absorption
(Chickpea)

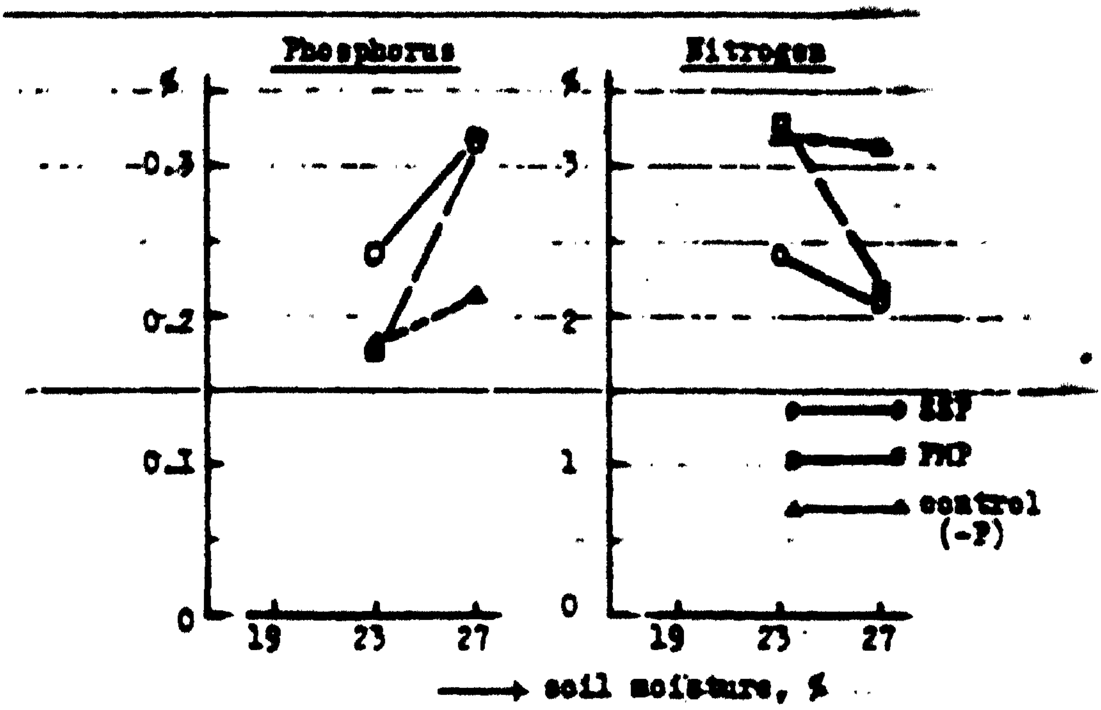

Figure 4, Phosphorus and nitrogen % in grain
(Chickpea)

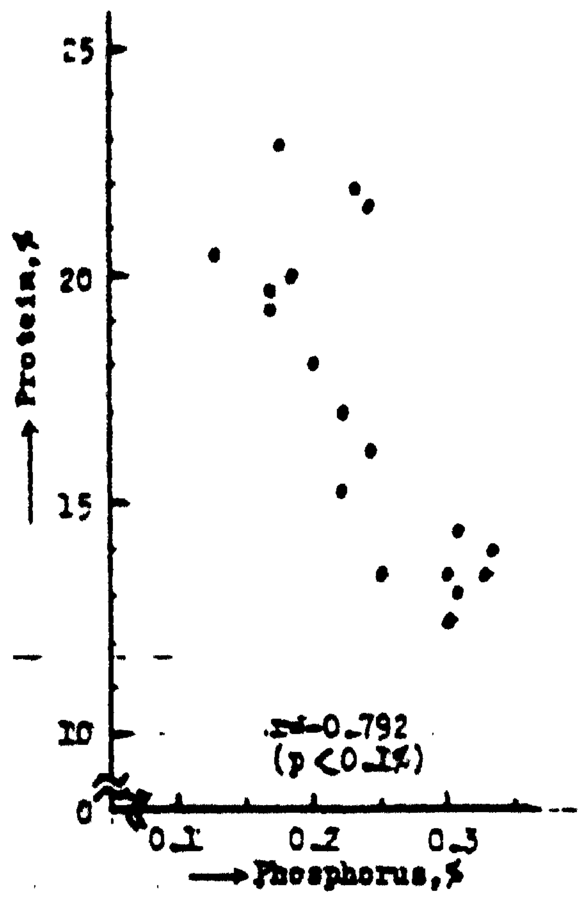

Figure 5, Relationship between phosphorus and protein % in grain (Chickpea)

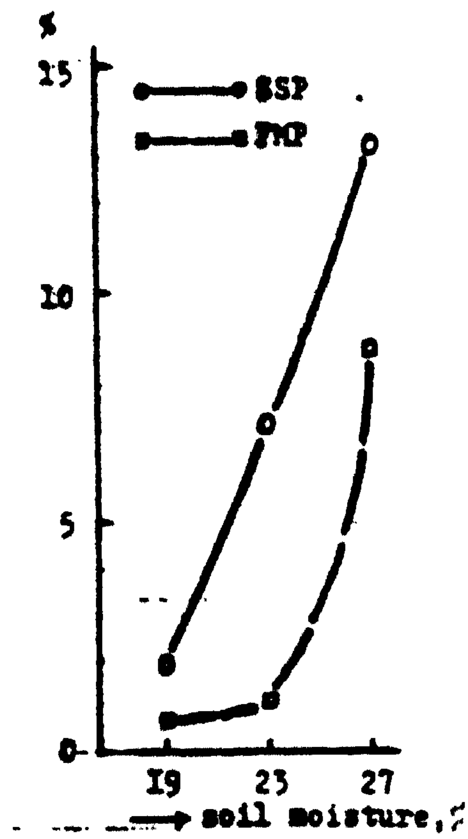

Figure 6, Absorption rate of phosphorus from phosphatic fertilisers (Chickpea)

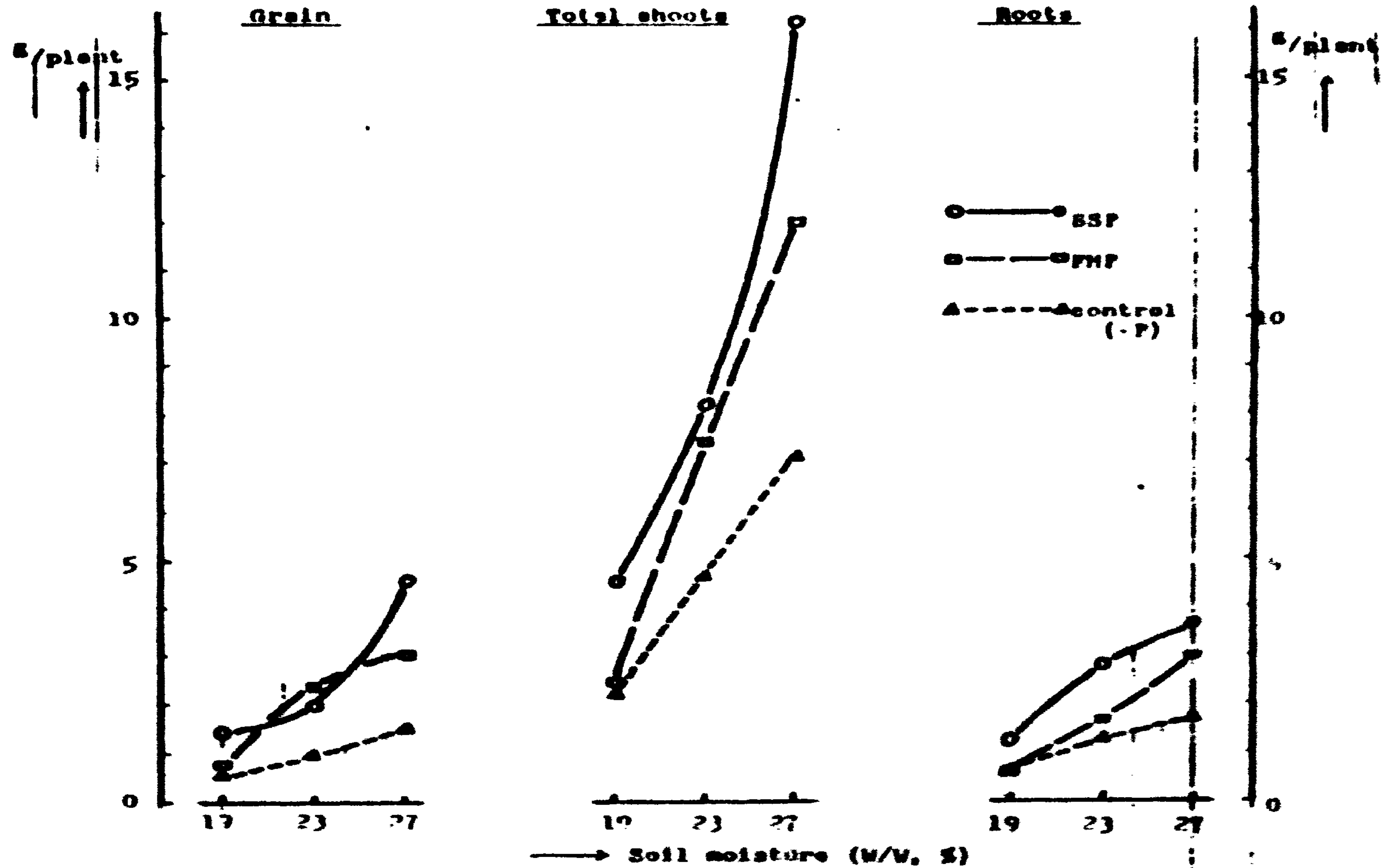

Figure 7. Effect of phosphatic fertilizers on yield and growth under three levels of soil moisture (Pigeonpea)

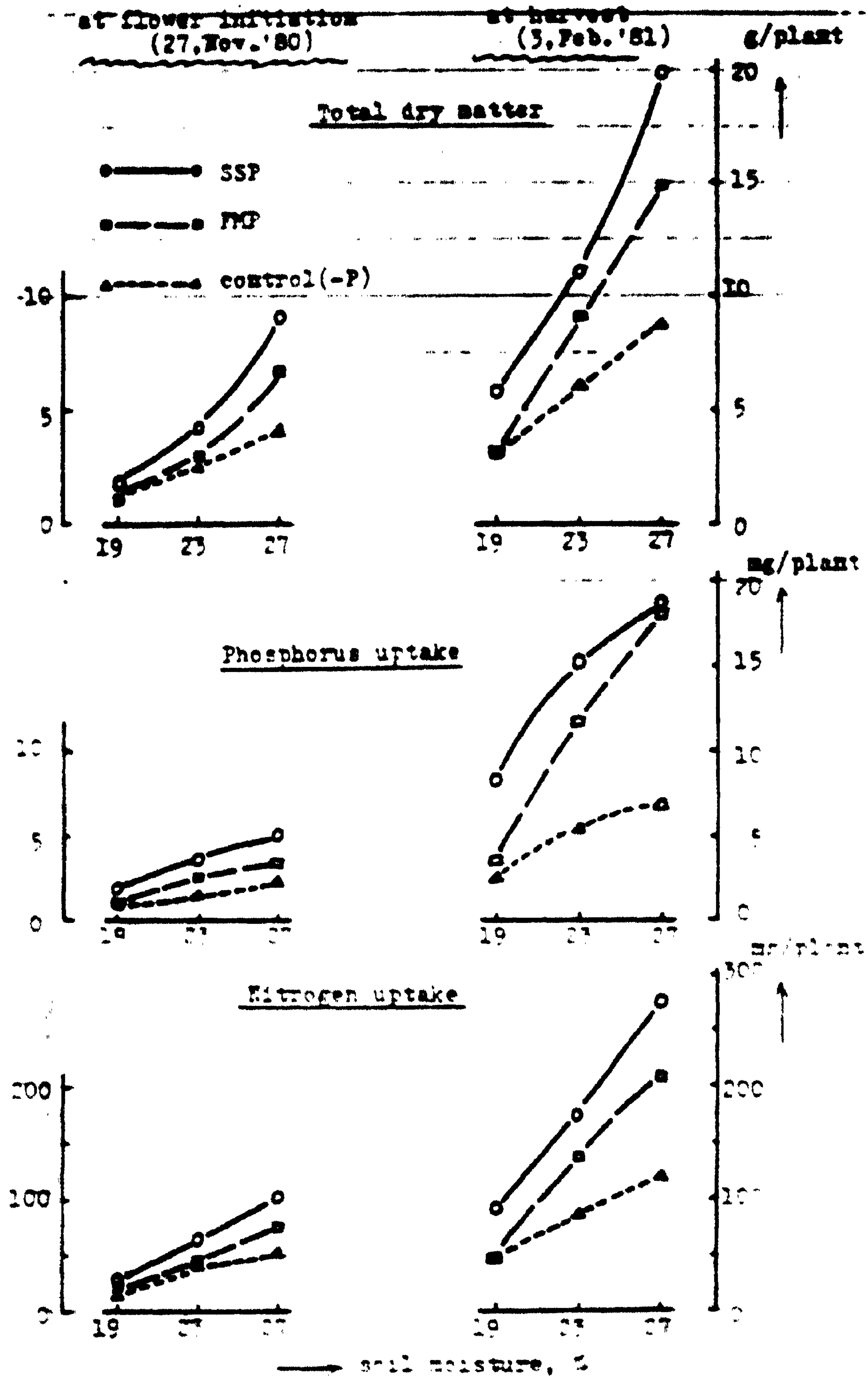

Figure 8. Growth, phosphorus and nitrogen uptake at two different stages (Pigeonpea)

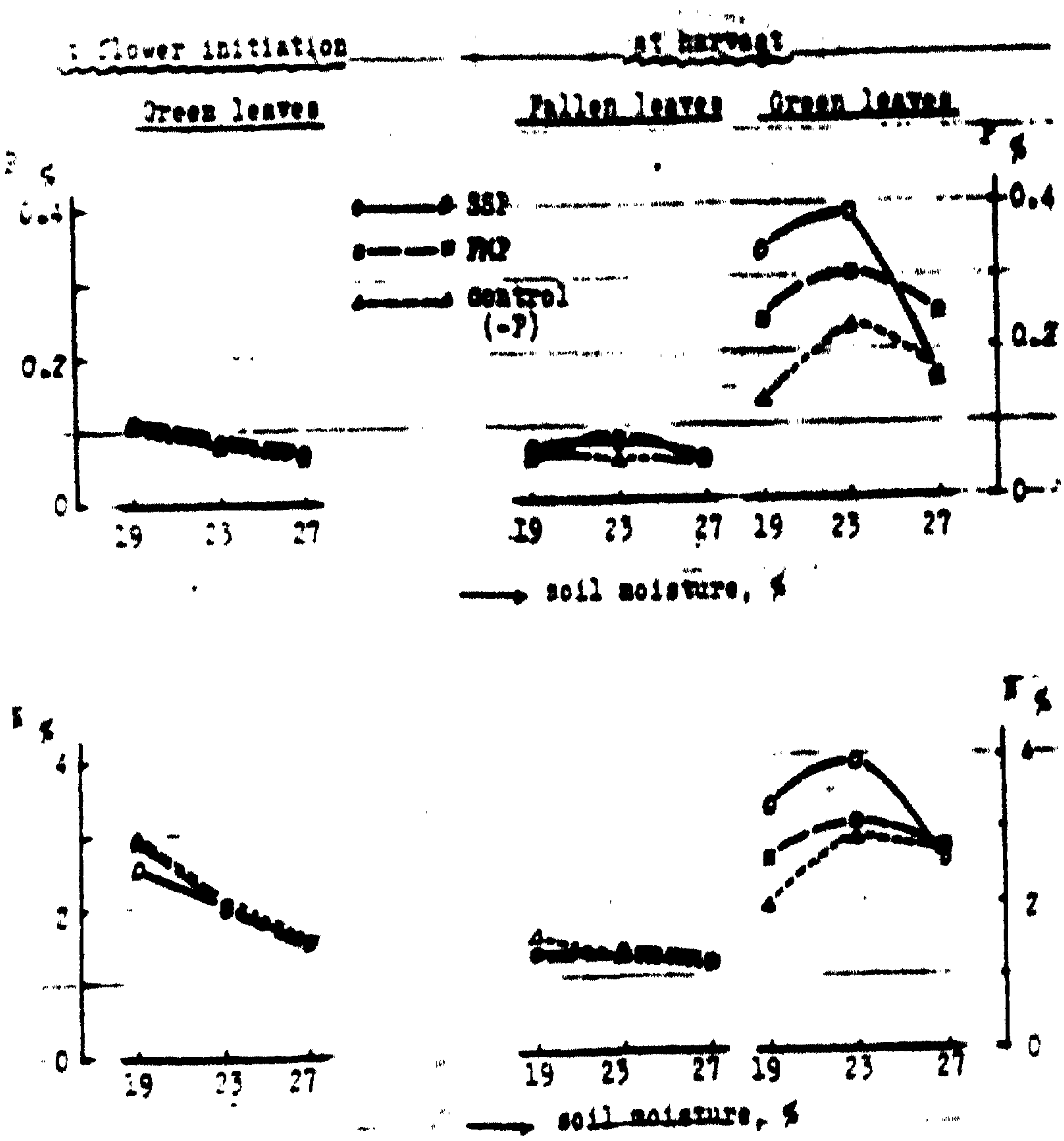

Figure 9, Phosphorus(upper) and nitrogen(lower) % in leaves at two different stages (Pigeonpea)

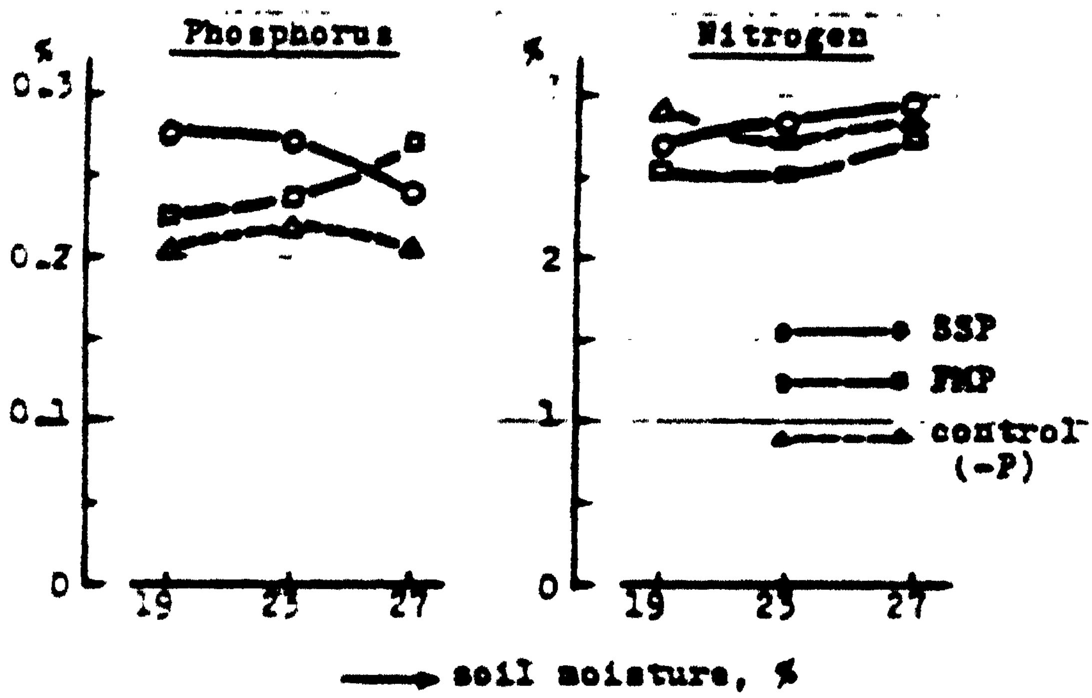

Figure 10, Phosphorus and nitrogen % in grain (Pigeonpea)

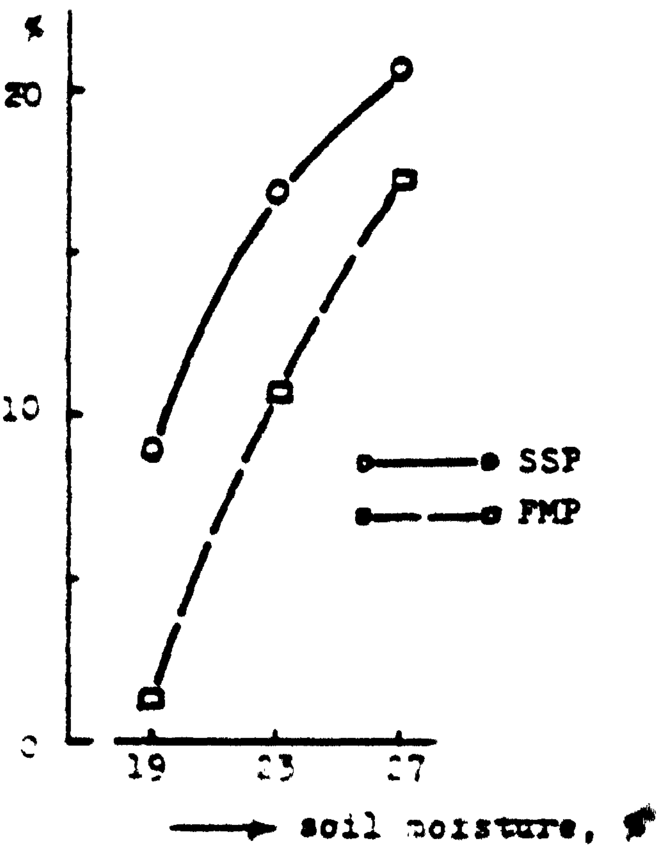

Figure 11, Absorption rate of phosphorus from phosphatic fertilisers (Pigeonpea)