EFFECT OF PHOSPHORUS NUTRITION, LIMING AND RHIZOBIAL INOCULATION ON SOYBEAN [*Glycine max* (L.) Merrill]

BY

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THESIS

Submitted in partial fulfilment of the requirement for the degree of

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D E C L A R A T I O N

I hereby declare that this thesis entitled "Effect of phosphorus nutrition, liming and rhizobial inoculation on soybean (*Glycine max* (L.) Merrill)" is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Vellanikkara,
December, 1979.

(T.M. KURIAN)

CERTIFICATE

Certified that this thesis is a record of research work done independently by Sri. T.M. Kurian under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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INTRODUCTION

INTRODUCTION

Soybean (Glycine max (L.) Merrill) is an excellent source of plant protein and vegetable oil. Although the crop has been cultivated in the hilly areas of our country since 1882, its large scale cultivation in the plains of North India came into practice only after 1960. Eversince then, efforts were made to popularise soybean among the farmers.

Intensive research work on soybean was started in G.B. Pant University of Agriculture and Technology, Pant Nagar and J.N. Krishi Vishwa Vidyalaya, Jabalpur in mid-sixties. As part of the co-ordinated project, a global germplasm collection was screened in various centres in India for selecting suitable types for the differential areas. Based on a similar trial at Coimbatore, 25 varieties were screened in as promising for South India. These 25 varieties were further tested for their performance in red loam soils of Trichur, since 1976. The variety EC 39821 (UGM 20) was found to be one of the most promising.

A nutritional trial on this crop was conducted during 1977 to study the nitrogen requirement and response to rhizobial culture inoculation (Nair,1978). With a view to standardise the nutritional requirements of the crop, it was considered necessary to continue experimental work on other fertiliser nutrients. Phosphorus application to legumes is generally treated as more important than non-legumes. This is so because this nutrient plays a dual role in legume cultivation both as a nutrient directly involved in the nutrition of the plant and also meeting the requirement of nitrogen fixing bacteria. Through the latter, the nitrogen supply to the plant is also decided to an extent by availability of phosphorus in the soil. Phosphorus status of the red loam soils of Kerala is generally rated as low and in general, response to fertiliser phosphorus is frequent.

As in the case of phosphorus, application of lime also is another management recommendation usually given in the case of legumes. Positive response to lime also is more frequently reported in legumes than in non-legumes. In addition to the direct involvement of meeting the requirement of calcium, this practice results in providing a more suitable medium to the growth of plant and also supplies this element for the growth and multiplication of nitrogen fixing bacteria. The lime status of soil optimum for the activity of rhizobial organisms is also generally considered to be higher than that for the direct crop nutrition.

It is well-known that for efficient symbiotic nitrogen fixation by legumes, presence of appropriate strains of the required rhizobial species is a must. For soybean, being a new introduction, the most effective strains of Rhizobium japonicum (the species responsible for nitrogen fixation in the cross-inoculation group of soybean) may not be available originally in the soil. In such a case, a drastic improvement in crop performance is to be normally expected because of culture inoculation. However, an experiment conducted during 1977 indicated a reverse trend of decrease in yield, nodulation and nitrogen uptake of soybean consequent to culture inoculation. It was then concluded that the soils probably contained effective strains of this species of Rhizobium and that the native strains were more effective than the strains introduced through the culture. As these results were quite contrary to expectation, it was felt necessary to check the results by repeating the treatments again. As mentioned earlier, two of the manageable environmental factors affecting efficient nitrogen fixation by legumes are the phosphorus availability and lime status of soil. It was therefore considered worthwhile studying the response to culture inoculation in combination with applied phosphorus and lime.

The present investigation was taken up with the following broad objectives in view.

i) To study the response of soybean to graded levels of applied phosphorus and to arrive at the requirement of this nutrient for soybean.

ii) To study the response of soybean to liming.

iii) To assess the effect of artificial culture inoculation.

iv) To study the interaction between these factors on soybean.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Experimental results on the influence of phosphorus application, liming and rhizobial inoculation on soybean yield were widely varying. Definite advantages due to increasing levels of phosphorus, liming and inoculation were often reported by workers from different parts of the world. But in contrast to this, lack of response or even negative response also were reported at times. A brief review of the research done on these lines is presented below.

1. Effect of applied phosphorus on growth atributes:-

Lutz and Jones (1975) observed that plant height increased significantly with increasing rate of phosphorus (in the trials conducted in the year 1971 and 1972). Application of phosphorus or phosphorus along with lime increased the height of plants (Ferrari, 1976). Similar increase in height of plant consequent to increase in phosphorus application was reported by Saleh (1976).

Bebin and Ignatenko (1969) found that phosphorus increased the leaf area index which was reflected in photosynthetic activity. Similar results were also noted by Roy and Mishra (1975). They found that soybean variety "Bragg" responded positively upto 31 kg phosphorus per hectare. Significant positive correlation between leaf area and number of pods per plant, hundred seed weight and seed yield were observed by Pal and Saxena (1977).

Mooy and John (1966) reported that nodulation in soybean required very high levels of phosphorus. Significant interaction between phosphorus and calcium with respect to nodule number was also reported by these workers. Corroboratory results were also obtained by Jones et al. (1977). According to Roy and Mishra (1975) application of phosphorus increased nodulation in soybean.

In the experiment conducted by Mooy and John (1966), significant increase in weight of root nodules was obtained due to interaction between phosphorus and calcium. Pereira et al.(1974) observed increase in nodule weight with higher levels of phosphorus. Although an increase in weight of nodules was observed by Roy and Mishra (1975), positive response was noticed only upto 30 kg phosphorus/ha.

Kesavan and Morachan (1973) reported that application of phosphorus increased the total dry weight of soybean plants. They also showed that such an increase in dry weight was observed only upto 100 kg P_2O_5/ha (in the case of EC 39821 selection of soybean), beyond which no increase was noted.

2. Effect of applied phosphorus on yield and yield attributes:-

Siva shankar et al. (1974) based on a field trial reported that application of phosphorus significantly increased the number of pods per plant and the number and yield of seeds per plant. A similar increase in pod number was reported in soybean by Saleh (1976).

Mascarenhas et al. (1968) in a field trial on a soil with a pH of 4.8 observed that soybean yield was increased by phosphorus application from 1.73 t/ha in control to 2.58 and 2.63 t/ha when 100 and 200 kg P_2O_5/ha respectively were given. Similar results were obtained by Chesney (1969). According to him increase in yield was from 1299 kg/ha in no phosphorus plot to 2177 kg/ha in plots given phosphorus at the rate of 132 kg/ha. Soybean when grown on soil of pH 5.5, gave significant linear response to phosphorus application. Mascarenhas et al. (1970) and Chatterjee et al. (1972)

revealed that on a well drained soil, soybean yield increased upto 80 kg P_2O_5/ha. Kesavan and Morachan (1973) in an experiment found increase in yield with increased rate of phosphorus application upto 100 kg P_2O_5/ha in the case of EC 39821 and 50 kg P_2O_5/ha in the case of EC 39824 selection of soybean. However, Tomar and Dev (1973) obtained linear increase in yield of soybean from 0 to 120 kg P_2O_5/ha in Gharnel area but at Raisen the increase was only upto 90 kg P_2O_5/ha. Baumgartner et al. (1974) noted increase in yield of soybean when phosphorus was applied at the rate of 80 kg P_2O_5/ha especially when applied with lime. Dutra et al. (1975) observed an increase in yield with increasing rate of phosphorus application. Phosphorus at the rate of 500 kg P_2O_5/ha increased the yield upto 2.76 from 1.76 t/ha when no phosphorus was applied, in the case of soybean variety "Santa Rosa" Lutz and Jones (1975a) reported that yield increased with phosphorus application. However its influence onsize of seeds was erratic. In the first year of trial, size of seeds was not affected by phosphorus but in the second year of study, it was observed that size decreased with increasing doses of fertilizer phosphorus. Similarly, Roy and Mishra (1975) noted positive response in yield only upto a phosphorus dose of 39 kg/ha. Braga et al. (1976) concluded that pH value and sum of base content were positively related to seed yield and to relative yield due to application of phosphorus. In another experiment, Ferrari (1976) observed that seed yield increased from 0.21 - 0.51 t/ha without applied phosphorus to 1.08 - 2.08 t/ha with 300 kg P_2O_5/ha.

Singh and Saxena (1973) found that applied phosphorus had no effect on soybean yield when the available phosphorus was high but yield increased with applied phosphorus, where available phosphorus was low. Kanki et al. (1974) found no response to high dose of applied phosphorus unless in the presence of molybdenum and lime. Mascarenhas and Kiihl (1974) also found lack of response in yield with increased rate of applied phosphorus. Based on an experiment Siva shankar et al. (1974) found that soybean variety "Hill" showed no significant increase in seed yield with application of phosphorus between 20 and 80 kg P_2O_5/ha but increase was observed from 3.7 t/ha without phosphorus to 4.48 t/ha when 40 kg P_2O_5/ha was applied in combination with 20 kg N and 40 kg K_2O/ha. Lutz and Jones (1975) found that soybean yield was unaffected by phosphorus during the first and second year but in the third year of experiment, yield was lowered in plot where phosphorus was applied. Sable and Khuspe (1976) investigated the effect of phosphatic fertilizer on the performance of soybean and found that the growth and yield remained unaffected due to phosphorus application. No seed yield increase was obtained in the experiment reported by Jones *et al.*(1977) to application of phosphorus beyond 15 kg/ha eventhough the soil was low in phosphorus. In a pot culture experiment it was found by Sable and Khuspe (1977) that phosphate did not influence grain or straw yield. Pod number and hundred grain weight also showed an irregular trend.

3. Effect of phosphorus on content and uptake of nutrients:-

Hanway and Weber (1971) in their experiment determined N, P and K contents in various plant parts at successive stages of development in nodulated and non-nodulated plants of soybean. Concentration of N, P and K in each plant part decreased except in the seeds as the season progressed in the N fertilizer trial and

P and K fertilizer trial. Fertilizer application increased the concentration of nutrient applied in all parts. Late in the season, P content increased especially in leaves, petioles and seeds in N deficient, non-nodulated plants that received no N fertilizer. Translocation to developing seeds resulted in marked depletion of nutrient in other plant parts irrespective of fertilizer application.

An increase in leaf calcium and leaf phosphorus consequent to the addition of phosphorus was reported by Pereira et al. (1974). Lutz and Jones (1975) observed increase in leaf phosphorus concentration with increase in applied phosphorus. Gupta (1977) based on a pot culture experiment reported that crude protein, true protein, phosphorus, magnesum and iron contents of soybean seeds increased under the influence of phosphorus. Singh and Saxena (1977) found that uptake of phosphorus by leaf lamina, leaf petiole and stem increased with age of the plant upto 65 to 80 days. Thereafter, increase was found only in the phosphorus content of stem and uptake of seeds. Uptake of phosphorus was found to increase with inoculation too.

In an experiment with nodulated and non-nodulated soybean plants, Hanway and Weber (1971) noted that phosphorus in plant parts decreased except in seeds, as season progressed. Translocation of this nutrient to developing seeds resulted in marked depletion of nutrient in the other plant parts. Singh and Saxena (1973) in contrast to the earlier findings, observed a decrease in recovery of phosphorus with increased amount of applied phosphorus. However, phosphorus content of lamina, petiole and total uptake by shoot at pod development stage was positively correlated with yield. Edwards and Barber (1976) observed that average net rate of inflex of phosphorus decreased with increasing age of soybean plants within a range of 18 to 74 days. Singh and Saxena (1977) found that in soybean plants after 80 days, phosphorus content decreased in lamina and petiole. There was also decrease in uptake of phosphorus by husk with advancing age. Concentration of phosphorus had also decreased in plant parts with inoculation.

4. Effect of liming on growth and growth attributes:-

Lutz and Jones (1975) based on their experiment

Lutz and Jones (1975) based on their experiment indicated that response of plant growth as a function of liming was erratic. In their study, it was found that in the first year (1971), plant height increased with liming, in the second year there was no effect and the third year (1973) there was negative effect due to lime application. There was no interaction effect between phosphorus and liming. Elkins (1976) observed that liming increased number of stems and vigour (plant height) compared to unlimed treatments in a soil of pH 4.9. But highest level at the rate of [illegible] t/ha did not influence these characters.

Alpete (1972) reported significant response to liming the soil to bring pH value from original to a range between 6.5 to 7.0, in mean yield of dry matter. Baumgartner et al. (1974) in a field experiment of soil with high organic matter content found that lime application 45 days before sowing significantly increased the yield of dry matter. Similar increase in dry matter yield of plant was reported by Mew and Vivekanandan (1975) when liming was done upto 1.4 tons/ha. of Ca O.

Martini et al. (1974) in an experiment under successive wheat and soybean cropping, found that liming significantly increased nodulation in plant.

Similar improvement in nodulation was observed by Chew and Vivekanandan (1975). Blevins et al. (1977) observed that low calcium significantly reduced nodule number and weight.

Franco and Dobereiner (1971) found two to three fold increase in nitrogen fixation with liming. Similar result was also reported by Chew and Vivekanandan (1975).

Lafti Getit (1974) reported that pod filling was delayed in unlimed plant possibly due to calcium, phosphorus and molybdenum deficiency or zinc, boron or manganese toxicity. Excess lime caused stunted growth, smaller leaves and failure of seed development probably due to phosphorus and zinc deficiency.

5. Effect of liming on yield of soybean:-

Mascarenhas et al. (1969) observed positive effect on yield with liming. However, Mascarenhas et al. (1970) found only a marginal response in yield in the second year of experiment (9% increase in yield). Martini et al. (1974); Chew and Vivekanandan (1975) and Ferrari (1976) also reported significant increase in crop yield due to liming the soil.

In contrast to the above observations, Mascarenhas et al. (1968); Mascarenhas et al. (1970); Lutz and

Jones (1975) found no conspicuous response to liming with respect to seed yield. Pevy *et al.* (1969) also observed no yield increase with liming in soybean except when given in combination with phosphorus in soils with pH between 5.0 and 5.6.

6. Effect of liming on content and uptake of nutrients:-

Elepete (1972) observed significant response to liming with respect to nitrogen uptake when pH is between 6.0 to 7.0. Although phosphorus had an increasing trend, the effect of liming was not significant. Manki *et al.* (1974) also found similar increase in nitrogen content of plant tissue consequent to liming together with phosphorus application. Martini *et al.* (1974) and Baumagrtner *et al.* (1974) also reported increase in total nitrogen content with liming.

(1972) reported decrease in phosphorus uptake by leaves and stem consequent to liming. Raul (1977) observed that although soybean was tolerant to high levels of exchangable aluminium, its performance was adversely affected when value surpassed 5.5 m.eq.per 100 g of soil in clay ultisol. Correlation existed between nitrogen content of leaf and yield. Nitrogen, phosphorus and calcium contents of the leaves were not affected by pH differences.

7. Effect of culture inoculation on growth:-

Rosas (1969) from his study reported that nodulation on fertile or moderately fertile soil increased plant height. Dry matter yield was found to be increased by seed inoculation and liming as reported by Chatterjee et al. (1972). Similar result was obtained by Lufti and Petit (1974) due to inoculation with *Rhizobium japonicum*. Dry matter of soybean was also found to increase in Nigeria when higher nitrogen dose was given in combination with inoculation (Kang, 1975).

Chatterjee et al. (1972) based on the result of a trial concluded that seed inoculation and liming increased nodulation. Hamdi et al. (1974) found that nodulation frequency, fresh weight of nodules and dry weight of pods increased with inoculation. Inoculated set was found to be better than uninoculated set in the field where it had not been cultivated before. Jansenvian et al. (1976) and Konova et al. (1976) observed that a strain of *Rhizobium japonicum* increased nodulation and nodule weight.

Katti *et al.* (1970) observed higher number and weight of nodules per plant when inoculated set was supplied with 80 kg P_2O_5/ha.

Pereira *et al.*(1974) reported that inoculation of soybean with *Rhizobium japonicum* was ineffective in a crop sown following potato due to the presence of *Bacillin polymyxa* which inhabited development of *Rhizobium japonicum*. Scudder (1975) observed a decrease in nodulation when inoculum was applied to seeds by coating or by mixing in hopper compared to that when placed in 2.5 to 5.0 cm below seed. Davidson and Reuser (1978) based on their experimental results suggested that application of excess quantity of *Rhizobium japonicum* to seeds is necessary. This permitted adequate number of organism to survive for nodulation. Nelson *et al.* (1978) on the other hand, did not find any increase in nodule mass per plant following inoculation of soil or seed with commercial inoculum.

8. Effect of culture inoculation on yield and nutrient content:-

Lufti and Detit (1974) observed that inoculation with *Rhizobium japonicum* increased seed yield per plant. Pod number and seed weight were increased by the application of higher doses of nitrogen along with inoculation of soybean in the experiment conducted by Kang (1975) in Nigeria. Konova *et al.* (1976) also found similar increase in thousand seed weight when inoculated with *Rhizobium japonicum*. Sable and Khuspe (1977) reported that inoculation increased pod number, pod weight and hundred seed weight.

Jethmalani (1969) observed that grain yield of soybean varieties "Bragg" and "Clark 63" receiving inoculation was significantly superior to the non-inoculated ones. Both inoculated and non-inoculated seeds showed significant response to phosphorus upto 80 kg P_2O_5/ha. Tuchapskii (1969) obtained highest yield from inoculated plants to which N, P_2O_5 and K_2O had been applied at 45 kg/ha each. Similarly higher yield was obtained by Katti *et al.* (1975) in their field trial when inoculation was combined with 80 kg P_2O_5/ha than when no phosphorus was applied. Chatterjee *et al.* (1972) found positive response in yield when inoculation and liming were resorted to. In another experiment, Kang, (1975) concluded that higher nitrogen application combined with inoculation on soybean increased yield. Konova *et al.* (1976) reported higher yield consequent to the application of *Rhizobium japonicum*. Sable and Khuspe

(1977) also got similar increase in yield with inoculation.

Belejova (1968) in an experiment on soybean with and without inoculation along with 40 kg N, 60 kg P_2O_5 and 80 kg K_2O/ha alone and in all combinations, found that yield was not affected by seed inoculation at all levels of potassium. From the results obtained by Rosas (1969), it was observed that nodulation on fertile or moderately fertile soil decreased yield of seed. In a trial by Singh et al. (1971), inoculation along with 20 - 40 kg N and 40 - 60 kg P_2O_5/ha gave little effect with respect to seed yield, seed oil, protein content etc.

Scudder (1975) observed that application of inoculum to the seed by coating or by mixing in the hopper gave decreased yield compared to placing it 2.5 to 5.0 cm below the seed. Nelson et al. (1978) reported that inoculation of soil or seed with commercial inoculant did not increase yield.

According to Sokorenko (1971) inoculation of soybean seeds markedly increased the total nitrogen content of plants when no fertilizer was given and when supplied with P and K but not when given N, P and K in combination. In another experiment, liming and seed inoculation had resulted in increased nitrogen, phosphorus and calcium contents of plants (Chatterjee *et al.*, 1972). Kang (1975) concluded that under Nigerian conditions, higher nitrogen application combined with inoculation of soybean increased nitrogen uptake and seed nitrogen content. Konova *et al.* (1976) found higher nitrogen content in the crop due to inoculation with *Rhizobium japonicum*.

MATERIALS AND METHODS

MATERIALS AND METHODS

The field experiment was conducted at the Instructional Farm attached to the College of Horticulture, Vellanikkara with the objective to study the response of soybean to different levels of phosphorus, liming and rhizobial inoculation.

1. Materials

1.1 Site and Soil.

The farm is situated at 10° 32" N latitude and 76° 10" longitude at an altitude of 22.25 metres.

The soil of the experimental area is deep, well drained, moderately acid, medium clay loam and fairly rich in organic matter. The chemical characteristics of the soil are given below.

Table 1. Chemical characteristics of soil.

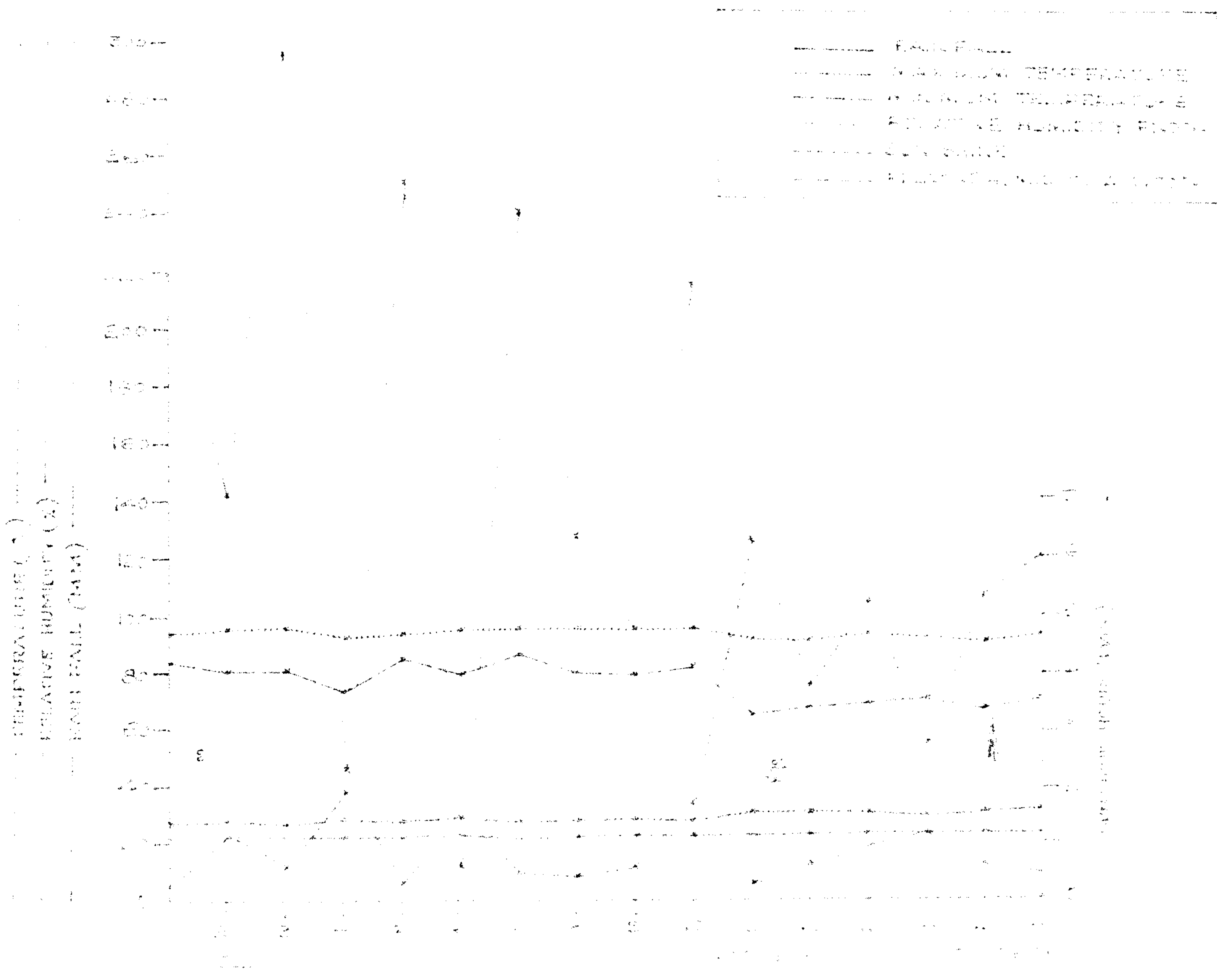
Constituent	Content in soil	Method used
Total nitrogen	0.0882%	Microkjeldahl
Total P_2O_5	0.1426%	In HCl extract, as ammonium phosphomolybdate volumetric method.

Constituent	Content in soil	Method used
Total K_2O	0.149%	In HCl extract, cobaltinitrate.
Total calcium	0.126%	In HCl extract, volumetric-permagnate method.
Available phosphorus	1.82ppm	In Bray-I extract, chloro-stannous reduced molybdo-phosphoric blue colour method.
Available potassium	275ppm	In neutral ammonium acetate extract - Flame photometric.
Exchangeable calcium	474ppm	In neutral ammonium acetate extract - Versene methods.
pH	6.0	1 : 2.5 soil : solution ratio using a pH meter.

1.2 Climate.

The area enjoys a humid tropical climate. The weekly average daily maximum temperature showed little fluctuations, the range for the entire period being 27.4°C to 31.3°C. The weekly average of the daily minimum temperature also varied only slightly, the average being 22.4°C to 23.7°C during the cropping season. The range of relative humidity was from 91% to 96% in the forenoon and 65% to 86% in the afternoon. The weekly variations in relative humidity were small. The total rainfall received during the crop

Fig-1 METEOROLOGICAL DATA FOR THE PERIOD FROM JULY TO OCTOBER 1975



season in 86 rainy days amounted to 1732.20 mm. There were rains during the entire period of crop season. However, most of it was received during the first ten weeks after sowing. The total quantity of rainfall received during these 66 rainy days was 1648.10 mm. The average daily rainfall of this period works out to be 23.54 mm. For the later period from eleventh to sixteenth week, rainfall was low. The number of rainy days during this period was 20, total rainfall 84.10 mm and the average daily 2.05 mm. The number of sunshine hours followed a reverse pattern, the daily average number of sunshine hours upto the tenth week being 0.99 hour per day and that during the later period was 4.82 hours per day. Sunshine recorded during the entire period ranged from 0.3 hour to 6.3 hours per week. The meteorological data, for the period are presented in Fig.1 and Table 1.

1.3 Season.

The experiment was conducted during the period from July to October 1978.

1.4 Cropping history.

The area was under rubber plantation before. It was cleared during 1975 and was under bulk crop of tapioca till 1976. Coconut was planted in the area during 1976 and the experiment was laid out in the interspace of coconut seedlings.

1.5 Variety.

The variety used was obtained from the Agricultural Botany Division, Tamil Nadu Agricultural University, Coimbatore. The material was originally an introduction from Thailand and the collection number assigned was EC 39821. It was released by Tamil Nadu Agricultural University under the name UGM 20.

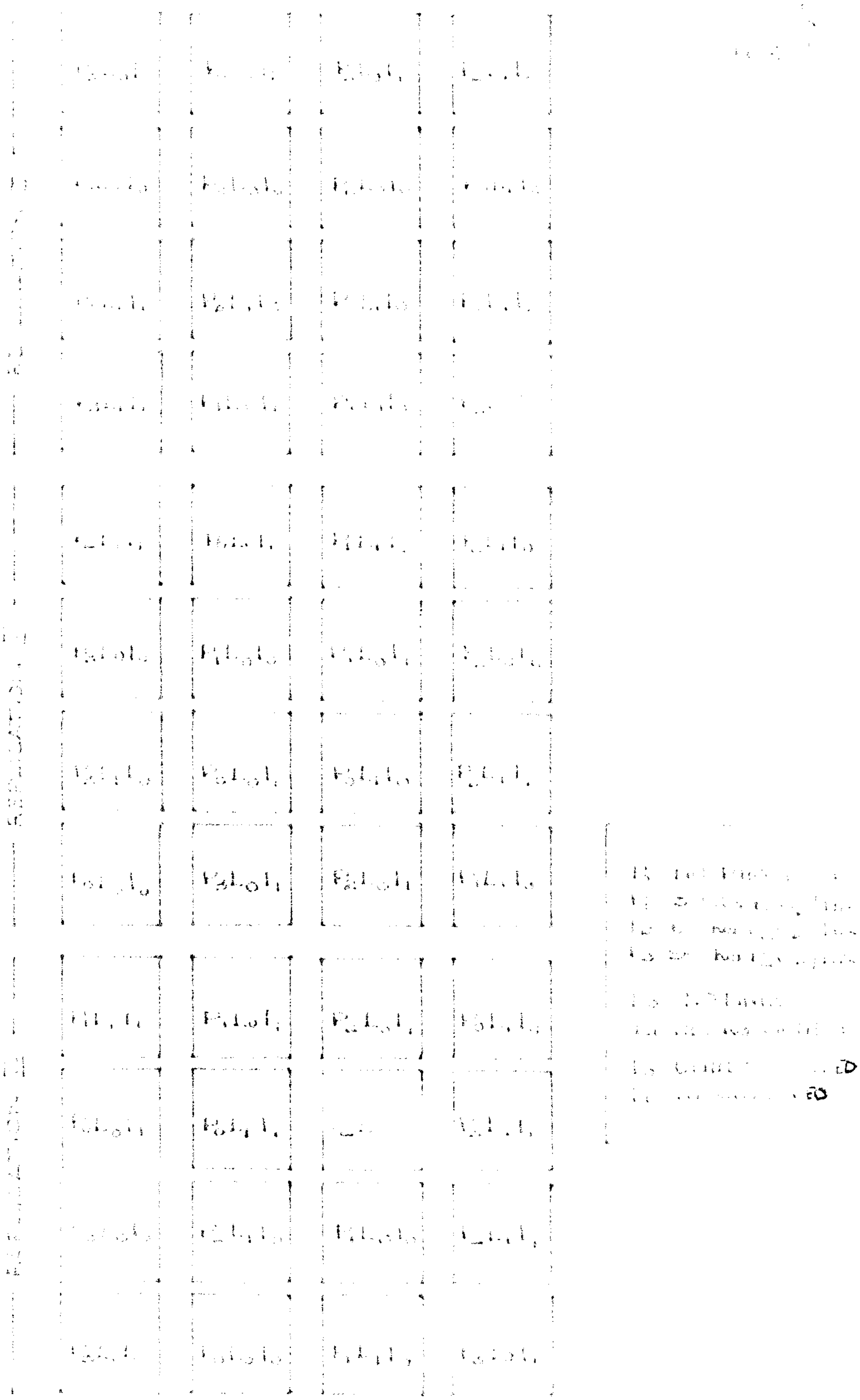
1.6 Fertilizers.

Ammonium sulphate, super phosphate and muriate of potash were used to supply the required quantities of nitrogen, phosphorus and potassium. Calcium hydroxide was used as liming material.

2. Methods.

2.1 Lay out of experiment.

The experiment was laid out as factorial in randomised block design with three replications. The procedure followed for the allocation of treatments to



different plots was in accordance with random table (Fisher and Yates 1963). The lay out plan is shown in Fig.2.

The details of the lay out are as follows:-

Number of replications	3
Number of plots per replication	16
Number of beds per plot	4
Bed size	4.5 m x 1 m

2.2 Treatments.

Treatments consisted of 16 combinations of 4 levels of phosphorus, 2 levels of lime and 2 levels of rhizobial inoculation. The details are furnished below.

P_0	Control (no phosphorus)
P_1	30 kg P_2O_5/ha
P_2	60 kg P_2O_5/ha
P_3	90 kg P_2O_5/ha

Levels of lime

L_o	Control (no lime)
L_1	250 kg lime/ha

Levels of rhizobial inoculation

I_o	Control (without inoculation)
I_1	Inoculated

Treatment combinations

$P_oL_oI_o$	$P_oL_oI_1$	$P_oL_1I_o$	$P_oL_1I_1$
$P_1L_oI_o$	$P_1L_oI_1$	$P_1L_1I_o$	$P_1L_1I_1$
$P_2L_oI_o$	$P_2L_oI_1$	$P_2L_1I_o$	$P_2L_1I_1$
$P_3L_oI_o$	$P_3L_oI_1$	$P_3L_1I_o$	$P_3L_1I_1$

2.3 Field culture.

2.3.1 Preparation of main field.

The field was ploughed with tractor and clods broken and weeds were removed. Beds of 4.5 m length and 1 m width were taken, separated by channels of 30 cm. width. Each plot consisted of four beds. Deep drainage channel was provided along the boundary and between the plots.

2.3.2 Liming and fertilizer application.

Lime was broadcast and raked in two weeks prior to sowing. Full dose of fertilizers were applied as basal dressing three days prior to sowing. Lime and fertilizers were applied as per schedule of treatments.

2.3.3 Seed treatment and sowing.

The procedure recommended by Tamil Nadu Agricultural

University was followed for treating the seeds with the culture (*Rhizobium japonicum*). Jaggery syrup was prepared, the culture was inturn added to the syrup and mixed thoroughly. The required amount of seeds as per schedule of treatments were then mixed with the culture and the seeds were subsequently dried in shade.

Sowing was done on 1-7-1977. Thirty seeds were dibbled in each row of the one metre wide bed at a distance of 45 cm between rows. Seedlings were thinned out a week after sowing to retain a population of 20 plants per row thus giving an average spacing of 5 cm between plants and 45 cm between rows.

2.3.4 Plant protection.

A mild attack of leaf eating caterpiller was noticed which could be effectively controlled by spraying malathion.

2.3.5 Weeding and earthing up.

Hand weeding and earthing up were done one month after sowing. Drainage channel was cleared and deepened to facilitate the flow of water at that time.

2.3.6 **Harvesting.**

The crop was ready for harvest 102 days after sowing. The stage of harvest was marked by complete defoliation. Plot-wise harvesting was carried out on 10-10-1978.

3. Observations Recorded

Following observations were recorded.

3.1 Growth characters.

1. Height of plant.
2. Number of branches.
3. Leaf area index.
4. Nodule count.
5. Nodule weight.
6. Number of pods per plant.
7. Number of seeds per pod.
8. Dry weight of stem and petiole.
9. Dry weight of leaves.
10. Dry weight of shell.
11. Dry weight of seeds.
12. Total dry weight of plant.
13. Net assimilation rate.

3.2 Observations at harvest.

1. Grain yield.
2. Stover yield.
3. Moisture percentage.
4. Test weight.
5. Shelling percentage.
6. Harvest index.

3.3 Chemical studies.

3.3.1 Plant analysis.

Plant components were analysed for the following nutrients on 20th, 50th and 80th day after sowing and at harvest stage.

A. Nitrogen content in different components.

i) Percentage of nitrogen in stem and petiole.
ii) Percentage of nitrogen in leaves.
iii) Percentage of nitrogen in seeds.
iv) Percentage of nitrogen in shell.

B. Phosphorus content in different components.

i) Percentage of phosphorus in stem and petiole.
ii) Percentage of phosphorus in leaves.

iii) Percentage of phosphorus in seeds.

iv) Percentage of phosphorus in shell.

3. <u>Calcium content in different components.</u>

i) Percentage of calcium in stem and petiole.

ii) Percentage of calcium in leaves.

iii) Percentage of calcium in seeds.

iv) Percentage of calcium in shell.

4. <u>Uptake of nitrogen by different components.</u>

i) Uptake of nitrogen by stem and petiole.

ii) Uptake of nitrogen by leaves.

iii) Uptake of nitrogen by seeds.

iv) Uptake of nitrogen by shell.

v) Total uptake of nitrogen by the plant

5. <u>Uptake of phosphorus by different components.</u>

i) Uptake of phosphorus by stem and petiole.

ii) Uptake of phosphorus by leaves.

iii) Uptake of phosphorus by seeds.

iv) Uptake of phosphorus by shell.

v) Total uptake of phosphorus by the plant.

F. Uptake of calcium by different components.

i) Uptake of calcium by stem and petiole.

ii) Uptake of calcium by leaves.

iii) Uptake of calcium by seeds.

iv) Uptake of calcium by shell.

v) Total uptake of calcium by the plant.

3.3.2 Soil analysis.

1. Total nitrogen content of the soil.
2. Total phosphorus content of the soil.
3. Total potassium content of the soil.
4. Total calcium content of the soil.
5. Available phosphorus in the soil.
6. Available potassium in the soil.
7. Exchangeable calcium in the soil.
8. pH of the soil.

These estimations were done on a pooled sample collected from different locations prior to sowing and on 16 pooled samples collected from respective treatments of the three replications after harvest.

4. Sampling Procedure.

One bed in each treatment and a row in this selected bed were marked at random. Five plants at a stretch were randomly selected and tagged to study the growth characters such as plant height and number of branches. Similarly, another set of five random plants at a stretch were selected at 20th, 50th and 80th days after sowing and at harvest and were removed by uprooting. These plants were used to study the number and weight of root nodules. Then the root portion was removed and plant components separated and bagged. These separated components namely stem + petiole, leaves, seeds and shell were used for further studies.

5. Details of Observation Procedure.

Procedure followed to study the characters is as detailed below:-

5.1 Height of plant.

Height of the selected five plants was measured from the ground level to the terminal bud. The average of the five plants was then worked out. The observation was made on 20th, 50th and 80th day after sowing.

5.2 Number of branches.

The number of branches of the same plants were counted on 50th and 80th day after sowing.

5.3 Leaf area index.

Ten leaves were selected at random from the selected five plants which were cut at the base and removed for the purpose. The impressions of these leaves were taken on quality bond paper of known weight per unit area. The paper was cut in the shape of sample leaves and weight of such 10 paper cuttings was taken. From this, the actual area of the sample leaves was calculated.

The leaves were dried in a hot air oven at 70°C to 80°C for three days and weight of the 10 sample leaves was recorded. Dry weight of the rest of the leaves was added to the dry weight of 10 sample leaves to get the total dry weight of the leaves of five plants. Leaf area of these five plants was computed from the dry weight of total leaves and the area per unit dry weight calculated from the area of 10 leaves.

Leaf area index was worked out as follows:-

$$\text{Leaf area index} = \frac{\text{Leaf area of five plants}}{\text{Land area occupied by five plants}}$$

5.4 Nodule count.

This observation was taken on the sample plants which were used for taking observation on leaf area index. These plants were uprooted and soil from the root was carefully removed. Total number of root nodules was counted and the average number of root nodules per plant was calculated.

5.5 Nodule weight.

Fresh weight of the nodules was taken. Average weight of nodules per plant was then worked out.

5.6 Number of pods per plant.

Average number of pods per plant was worked out by counting the total number of pods from the five sample plants taken at harvest for recording other observations like dry weight and leaf area index.

5.7 Number of seeds per pod.

Ten pods were selected at random from the above sample plants. Total number of seeds was counted and average number of seeds per pod was calculated.

5.8 Dry weight of shoot.

Five sample plants uprooted on 20^{th}, 50^{th} and 80^{th} day after sowing and at harvest were used for determining the dry weight of shoot. Immediately after the leaves were separated and bagged, the same were dried in a hot air oven at a temperature of 70° to 80°C for 3 days and then dry weights was taken. Dry weights of stem + petiole and leaves was recorded separately and they were subsequently added up to get the total dry weight. On the 80th day and at harvest, pods were also separated from the plants. The pods were then separated into seed and shell and their dry weight was also determined separately. For calculating total dry weight at these two stages the weight of pods was also added to the weight of leaves and stem + petiole.

5.9 Dry weight of seeds and shell.

On the 80th day and at harvest, pods from the sample plants were separated and they were further separated into seeds and shell. These were dried separately and their dry weight was determined.

5.10 Net assimilation rate.

The procedure given by Watson (1958) as modified by Buttery (1970) was followed.

The equation used was the following:-

$$NAR = \frac{W_2 - W_1}{t_2 - t_1 \frac{(A_1 + A_2)}{2}}$$

Where,

W_2 = Total dry weight of plants/m^2 at time t_2.

W_2 = Total dry weight of plants/m^2 at time t_1.

$t_2 - t_1$ = Time interval in days.

A_2 = Leaf area/m^2 at time t_2.

A_1 = Leaf area/m^2 at time t_1.

5.11 Grain yield.

Crop was harvested from the net plots, threshed, winnowed and cleaned. Grains were sundried and weight recorded. Samples of seeds were collected from each plot for determination of moisture. The data on the percentage of moisture were analysed statistically and the differences were found to be non-significant. Adjustment of yield data for moisture correction was therefore not done. A total of 45 sample plants were removed from the plots upto the harvest stage. While calculating the yield, the size of the net plot was calculated taking into account the area occupied by these samples.

5.12 Stover yield.

Stover from each plot was sundried and weighed separately.

5.13 Shelling percentage.

Shelling percentage was calculated from the dry weight of grain and dry weight of pods of the five sample plants using the following formula.

$$\text{Shelling percentage} = \frac{\text{Dry weight of seeds}}{\text{Dry weight of pods}} \times 100$$

5.14 Harvest index.

Harvest index was calculated as follows:-

$$\text{Harvest index} = \frac{Y\ \text{econ}}{Y\ \text{biol}}$$

Where,

Y econ = Dry weight of grains

Y biol = Total dry weight of plants (excluding roots)

The five sample plants used for taking observations on dry weight were used for this purpose also.

6. Chemical Analysis.

Plant samples taken on the 20th, 50th and 80th day after sowing and at harvest were used for chemical analysis. Sample plants were separated into different components, viz: stem + petiole, leaves, seeds and shell and bagged separately. The different components were oven dried to constant weight and ground for the determination of total nitrogen, phosphorus and calcium contents.

6.1 Total nitrogen content.

Total nitrogen was estimated by Microkjeldahl procedure as given by Jackson (1958).

6.2 Total phosphorus content.

Phosphorus content was estimated colorimetrically (Jackson, 1958) after wet digestion of the sample using triacid mixture and developing colour by the molybdo-phosphoric yellow colour method.

6.3 Total calcium content.

Total calcium content in plant was estimated by the Versene titration (Jackson, 1958) after wet digestion of the sample using tri-acid mixture.

6.4 Uptake of nitrogen.

Total uptake of nitrogen was calculated from the nitrogen percentage and dry weight of the component. The uptake values of the different components were added to get the total nitrogen uptake.

6.5 Uptake of phosphorus.

This was calculated from the total phosphorus content and the dry weight of the component. The total uptake of phosphorus was calculated from the uptake of the different components.

6.6 Uptake of calcium.

Uptake of calcium was calculated from the calcium content and dry weight of the components. Total uptake of calcium was also calculated.

6.7 Soil analysis.

A composite soil sample from the experimental plot was taken prior to lay out for the analysis of total nitrogen, total phosphorus, total calcium, total potassium, available phosphorus, available potassium, exchangeable calcium and for the measurement of pH. Similarly, soil samples were taken from each treatment after the experiment and the composite samples pooled over the replications were used for the estimation of total nitrogen, available phosphorus, available potassium and exchangeable calcium.

7. Statistical Analyses.

Data on yield, yield attributes, growth characters and those on chemical analysis were analysed statistically by following the methods suggested by Snedecor and Cochran (1967), 'F' test was carried out by analysis of variance method. Critical difference was worked out and significant results were compared.

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

The results of the experiment as influenced by various treatments are presented in the following text with the help of Tables and suitable figures.

1. Growth Characters

1.1 Height of plants.

Data on the mean height of plants are presented in Table 2 and Fig. 3 and the analysis of variance is given in Appendix II.

Different levels of phosphorus did not produce any significant effect on plant height at any of the three stages of growth. However, 90 kg P_2O_5/ha recorded the maximum mean height at all the three stages of growth.

Liming also did not exert any significant effect on the height of plant but for a slight increase noted on the 50^{th} and 80^{th} day after sowing.

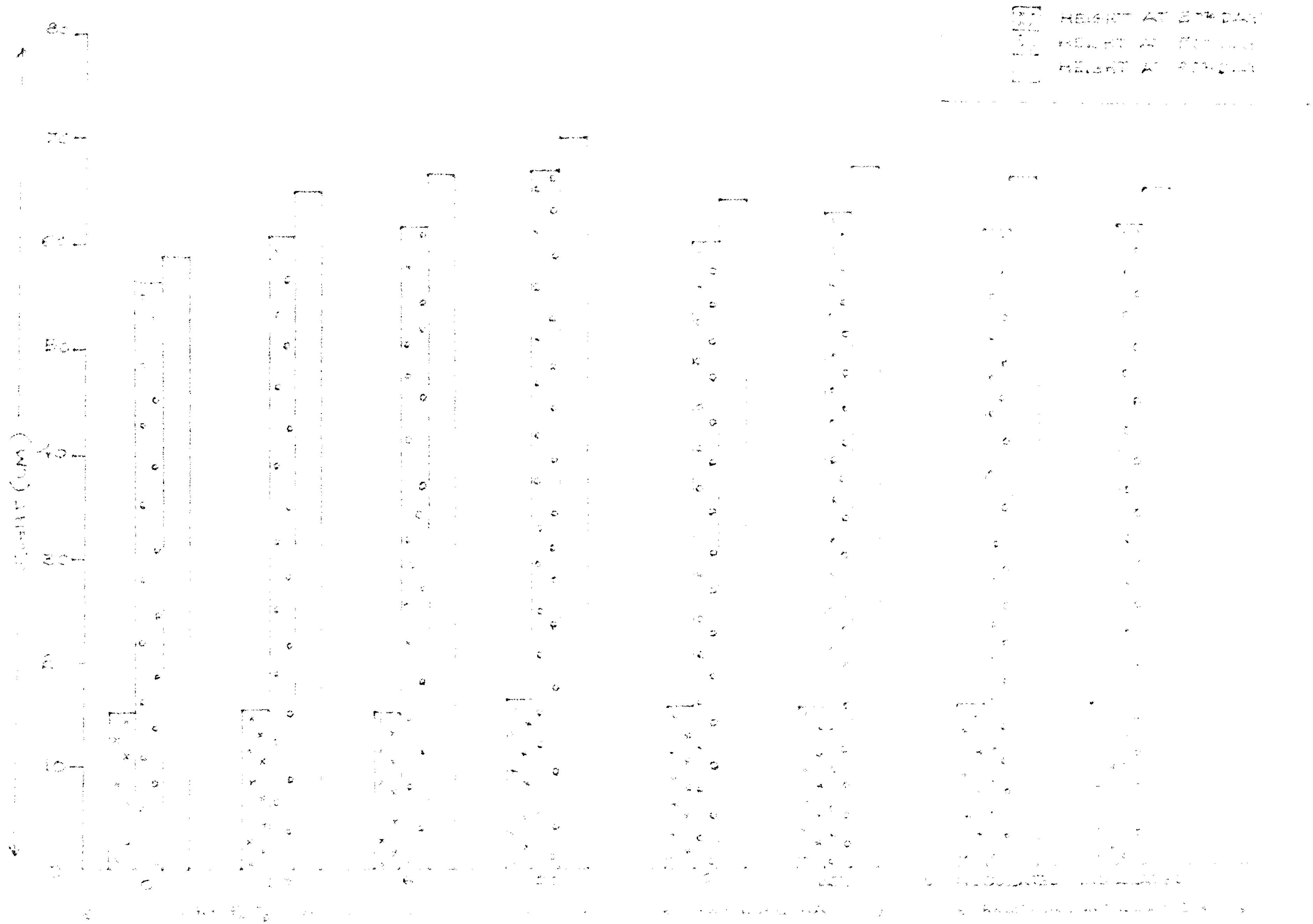
Rhizobial inoculation of seeds did not have any significant effect at any of the stages of growth. Uninoculated treatment was on par with the inoculated treatment.

Table 2. Effect of phosphorus nutrition, liming and rhizobial inoculation on height of plants and number of branches.

TREATMENTS	Height of plants (cm)			Number of branches	
	20th day after sowing	50th day after sowing	80th day after sowing	50th day after sowing	80th day after sowing
Levels of phosphorus ($Kg\ P_2O_5/ha$)					
0	15.27	56.72	59.24	2.856 (1.690)	3.236 (1.799)
30	15.25	60.57	65.22	2.759 (1.661)	3.683 (1.919)
60	15.07	61.36	66.77	2.736 (1.654)	3.591 (1.895)
90	16.49	66.76	70.01	2.955 (1.719)	3.471 (1.863)
F' test	NS	NS	NS	NS	NS
SEm ±	0.468	3.150	3.685	0.051	0.070
CD at 5%	-	-	-	-	-
Levels of lime (Kg/ha)					
0	15.54	60.04	63.97	2.806 (1.675)	3.353 (1.831)
250	15.49	62.67	62.67	2.849 (1.688)	3.637 (1.907)
F' test	NS	NS	NS	NS	NS
SEm ±	0.332	2.227	2.606	0.032	0.050
CD at 5%	-	-	-	-	-
Rhizobial inoculation					
Uninoculated	15.47	61.30	65.89	2.799 (1.673)	3.463 (1.861)
Inoculated	15.57	61.40	65.23	2.856 (1.690)	3.519 (1.876)
F' test	NS	NS	NS	NS	NS
SEm ±	0.332	2.227	2.606	0.032	0.050
CD at 5%	-	-	-	-	-

Figure in parenthesis indicate root (x) transformed values.

Fig. 2 HEIGHT OF PLANTS AS AFFECTED BY DIFFERENT LEVELS PHOSPHORUS, LIMING AND RHIZOBIAL INOCULATION.



Interaction effects between phosphorus, liming and inoculation were not significant at any of the stages of growth.

The review of literature on the effect of phosphorus on plant height generally shows an increased height with phosphorus supply (Lutz and Jones, 1975a; Saleh, 1976 and Ferrari et al. 1976) indicating thereby that plant height in soybean is a character that improves with phosphorus application. The lack of significant increase in height in the present investigation thus points to the fact that the inherent phosphorus supply was adequate in the soil to maintain growth of the plant in terms of plant height. There are also reported evidences on a decrease in height of soybean with increased levels of applied phosphorus (Kesavan and Morachan, 1973) probably in soils containing excess quantities of phosphorus originally. Such a decrease was not noticed in the present work.

Similar reports of both favourable and unfavourable effects of liming on plant height are also available in literature. Lutz and Jones (1975a) reported

Lutz and Jones (1975a)

an increase in plant height because of liming in the experiments conducted during 1971. They found that plant height remained unaffected in their experiment conducted during 1972, and decreased in that of 1973, because of liming. Elkins (1976) also found increased height because of liming but Lufti and Oetit (1974) noticed stunting of plants because of overliming. As indicated by the above review, it appears that there is an optimum pH range of soil for different varieties of soybean. Lack of significant effect of liming on height in the present investigation points to the fact that original pH of the soil (6.0) was within the optimum pH for this variety. The results also show that application of lime at 250 kg/ha could not raise the pH to super optimal levels for growth as measured by height of plants.

There was no significant effect on plant height because of culture inoculation. This probably is because nitrogen supply to the plant through symbiotic nitrogen fixation could not be appreciably altered by culture inoculation.

1.2 Number of branches.

The data for number of branches are presented in

FIG. [illegible] NUMBER OF BRANCHES AS AFFECTED BY DIFFERENT LEVELS OF [illegible]

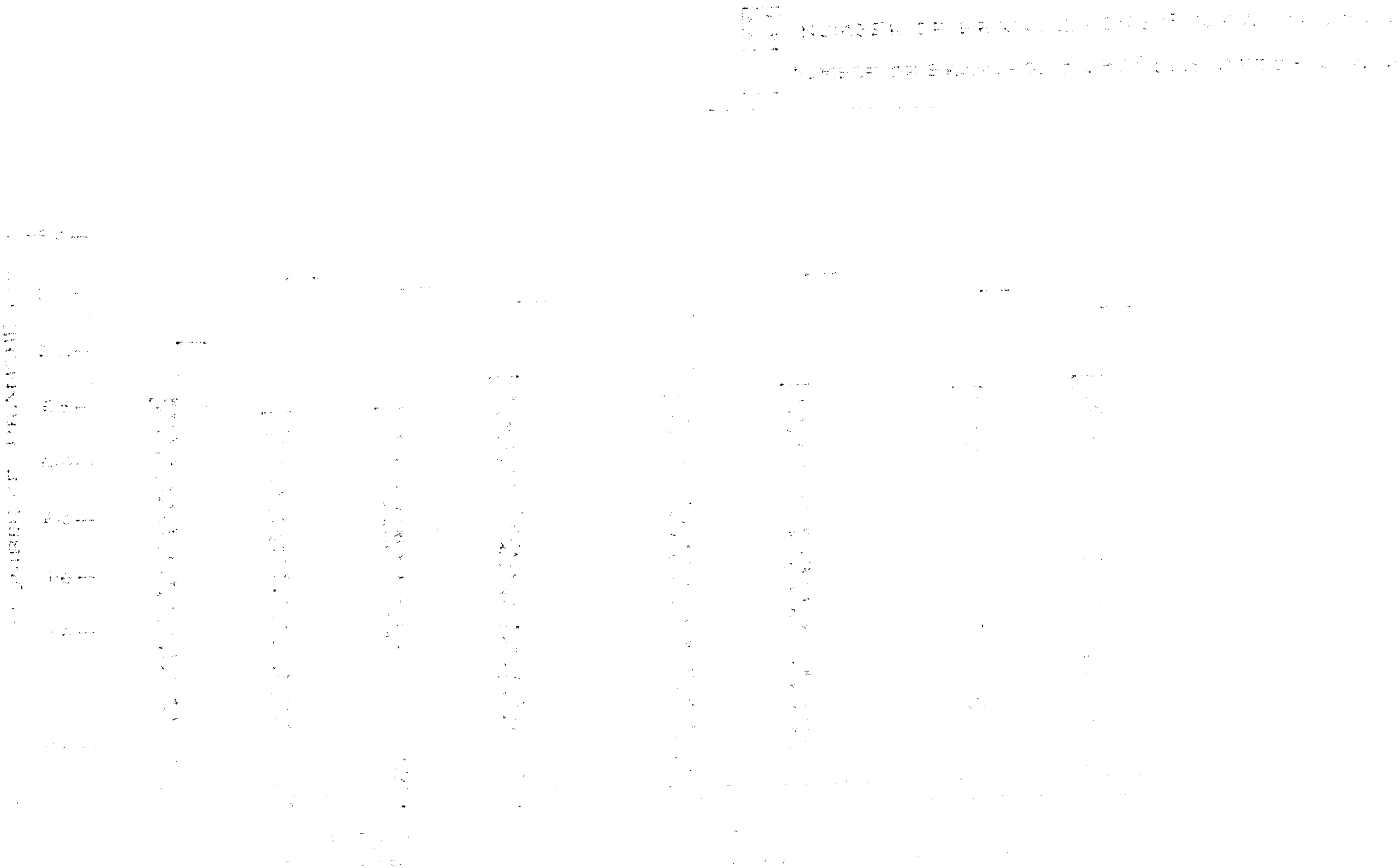


Table 2 and Fig. 4 and the analysis of variance is given in Appendix II.

The data presented show that there was no significant effect of phosphorus on the number of branches either on the 50th day or on the 80th day after sowing. However, a very slight increase was noticed with 90 kg P_2O_5/ha on the 50th day after sowing but this trend was not retained on the 80th day.

Liming and inoculation did not influence the number of branches significantly except for the fact that limed and inoculated treatments were slightly superior to control. Interaction effects were not significant at any of the stages.

As in the case of plant height, there was no significant effect of phosphorus application, liming and inoculation on number of branches also. The reasons attributed to the lack of significant increase in plant height are attributable in the case of number of branches also.

1.3 Leaf area index (L.A.I.).

Data on leaf area index are presented in Table 3

Table 3. Effect of phosphorus nutrition, liming and rhizobial inoculation on leaf area index and net assimilation rate.

TREATMENTS	Leaf area index			Net assimilation rate $g/m^2/day$	
	20th day after sowing	50th day after sowing	80th day after sowing	Between 20th and 50th day after sowing	Between 50th & 80th day after sowing
Levels of phosphorus ($Kg\ P_2O_5/ha$)					
0	0.379	3.657	3.393	3.265	3.080
30	0.458	3.807	3.625	3.382	3.628
60	0.358	4.097	4.183	2.950	4.118
90	0.437	4.758	5.438	3.389	3.357
F' test	Sig	NS	NS	NS	NS
SEm ±	0.028	0.340	0.436	0.187	0.550
CD at 5%	0.080	-	-	-	-
Levels of lime (Kg/ha)					
0	0.396	4.071	4.201	3.113	3.659
250	0.420	4.087	4.118	3.380	3.432
F' test	NS	NS	NS	NS	NS
SEM ±	0.020	0.241	0.308	0.132	0.389
CD at 5%	-	-	-	-	-
Rhizobial inoculation					
Uninoculated	0.396	3.999	4.220	3.252	3.550
Inoculated	0.420	4.159	4.099	3.241	3.542
F' test	NS	NS	NS	NS	NS
SEm ±	0.020	0.241	0.308	0.132	0.389
CD at 5%	-	-	-	-	-

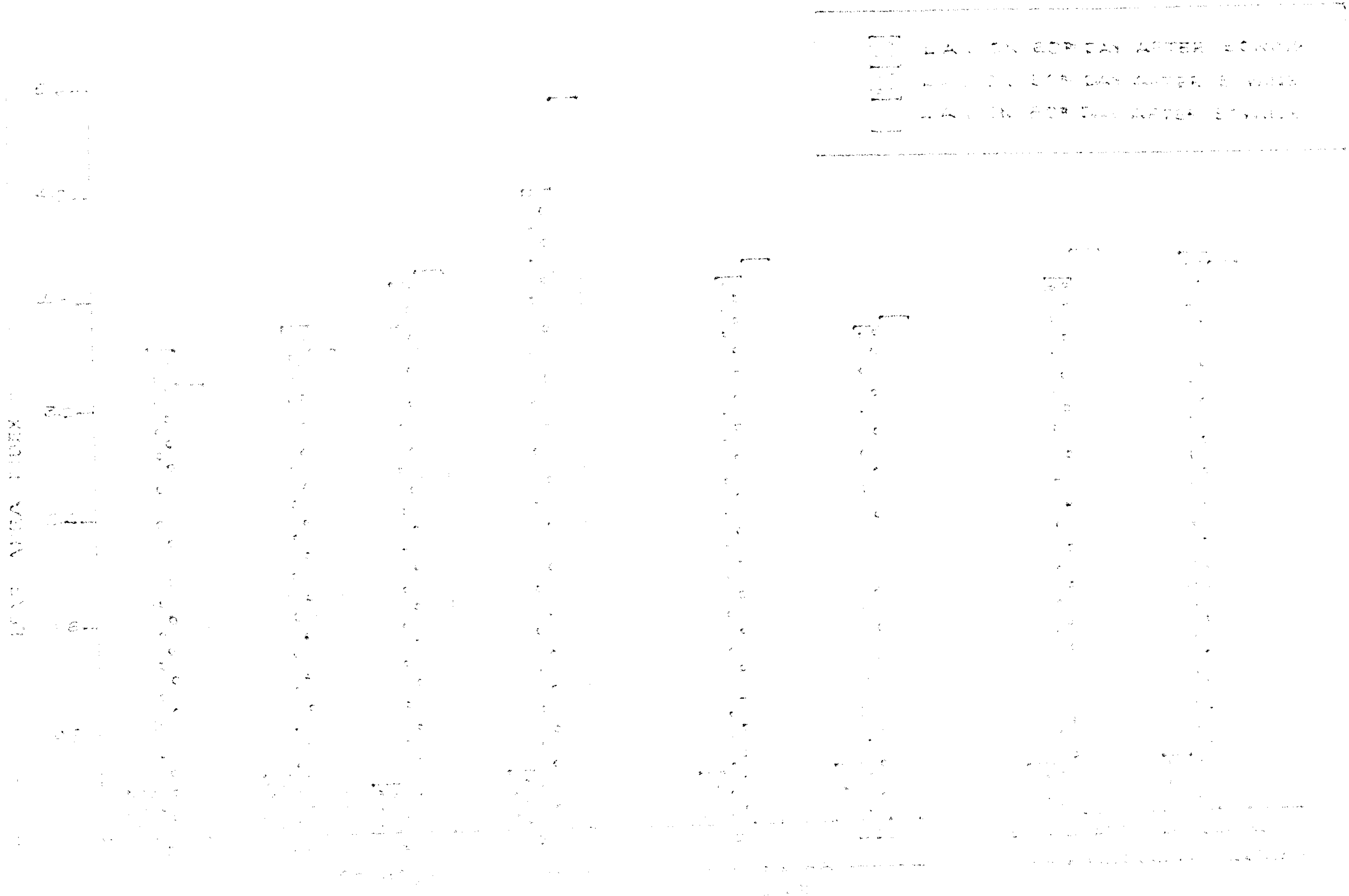
Table 3 a. Combined effect of phosphorus and liming on leaf area index on the 20th day after sowing

Levels of phosphorus (Kg P_2O_5/ha)	Levels of lime (Kg/ha) 0	250	Mean
0	0.384	0.374	0.379
30	0.426	0.489	0.458
60	0.425	0.291	0.358
90	0.348	0.526	0.437
Mean	0.396	0.420	0.408

SEm ± 0.039

CD at 5% 0.113

LEAF AREA INDEX AS AFFECTED BY DIFFERENT LEVELS OF PHOSPHORUS, LIME AND RHIZOBIAL INOCULATION.



and Fig. 5 and analysis of variance is given in Appendix III.

Levels of phosphorus did not influence leaf area index significantly on the 50th or 80th day after sowing but on the 20th day, P_2O_5 at 30 kg/ha was significantly superior to that of 60 kg/ha. In the second and third stages of growth, although the highest level of phosphorus was on par with other levels, a steady increase in L.A.I. was observed with increasing doses of this nutrient.

With levels of liming and inoculation slight increase in L.A.I. was observed on 20th and 50th day after sowing. On the other hand, at the third stage higher L.A.I. was recorded in treatments where no lime was applied or where seeds were sown uninoculated. However, treatments were found statistically at par, both in the case of liming and inoculation.

Interaction between phosphorus and liming was found to be significant on the 20th day. The highest level of phosphorus, 90 kg P_2O_5/ha along with lime at 250 kg/ha gave the highest mean L.A.I. value. However, the results do not indicate a consistent positive interaction between levels of phosphorus and liming. At the other stages of observation, the interaction between these treatments was not significant. Similarly, the interaction between phosphorus and inoculation and that between liming and inoculation were not significant at any other stage.

Unlike plant height and number of branches, L.A.I. showed a distinct trend of increase with increasing levels of phosphorus, though the effect was significant only at the first stage. While discussing the characters, plant height and number of branches, it was concluded that the inherent supply of phosphorus was adequate in terms of these two characters. In terms of L.A.I., on the contrary, the original phosphorus supply in the soil was not adequate as evidenced by the increase in this character with increase in the level of phosphorus. Such differences indirectly indicate that phosphorus requirement for maintaining optimum leaf growth is not the same as that for plant height and number of branches.

The effect of phosphorus on increase in leaf area may be either direct or through its effect on increased nitrogen supply through symbiotic nitrogen fixation. Such a positive interaction between phosphorus application and nitrogen accumulation will be discussed further while dealing with nitrogen uptake.

The effects of liming and inoculation were not significant and consistent. The reasons for these have been discussed earlier.

1.4 Net assimilation rate.

Data on the net assimilation rate are presented in Table 3 and the analysis of variance is given in Appendix III.

Levels of phosphorus, liming and rhizobial inoculation did not affect net assimilation rate significantly. Interaction was also not significant.

Net assimilation rate which is the measure of the efficiency of the leaves to photosynthesis was not found to be affected significantly by any of the treatments. It is generally expected that net assimilation rate will decrease with increase in leaf area index especially at higher L.A.I. values. In the present study, there was no such consistent relation noticed indicating thereby that L.A.I. was not high enough to exert any significant mutual shading. It may be recalled that L.A.I. also did not show any significant treatment variation. It was expected that over the stages, there would be a decrease in net assimilation rate as the L.A.I. increased substantially with advancing age. Such a trend was also not apparent in the study though the mean L.A.I. at 50th day and 80th day after sowing was round about 4. It may be concluded therefore that even this L.A.I. did not result in significant mutual shading.

1.5 Dry weight of stem and petiole.

Data on dry weight of stem and petiole at various stages are given in Table 4 and Fig.6 and the analysis of variance is given in Appendix IV.

Higher levels of phosphorus tended to increase dry matter production at all the four stages but the differences were not statistically significant. On 20th day and 50th day after sowing, the increase in dry matter was observed with increasing levels of phosphorus. At harvest, 30 kg P_2O_5/ha produced less dry matter than

Table 4. Effect of phosphorus nutrition, liming and rhizobial inoculation on the dry weight of stem and petiole.

TREATMENTS	Dry weight of stem and petiole (g)			
	20th day after sowing	50th day after sowing	80th day after sowing	Harvest
Levels of phosphorus ($Kg\ P_2O_5/ha$)				
0	0.692	15.34	23.83	20.20
30	0.784	17.36	26.53	18.84
60	0.737	15.56	30.43	22.26
90	0.823	20.76	34.58	23.50
F' test	NS	NS	NS	NS
SEm ±	0.046	1.53	2.85	2.27
CD at 5%	-	-	-	-
Levels of lime (Kg/ha)				
0	0.736	16.40	28.85	21.14
250	0.770	18.10	28.83	21.26
F' test	NS	NS	NS	NS
SEm ±	0.033	1.08	2.01	1.61
Rhizobial inoculation				
Uninoculated	0.721	16.84	20.62	20.63
Inoculated	0.785	17.67	29.07	21.78
F' test	NS	NS	NS	NS
SEm ±	0.033	1.08	2.01	1.61
CD at 5%	-	-	-	-

Table 4 a. Combined effect of phosphorus and liming on the dry weight of stem and petiole (g/5 plants) on the 20th day after sowing

Levels of phosphorus ($Kg\ P_2O_5/ha$)	Levels of lime (Kg/ha) 0	250	Mean
0	0.695	0.643	0.669
30	0.720	0.648	0.724
60	0.658	0.715	0.737
90	0.715	0.930	0.823
Mean	0.736	0.770	0.753

Sem ± 0.063
CD at 5% 0.187

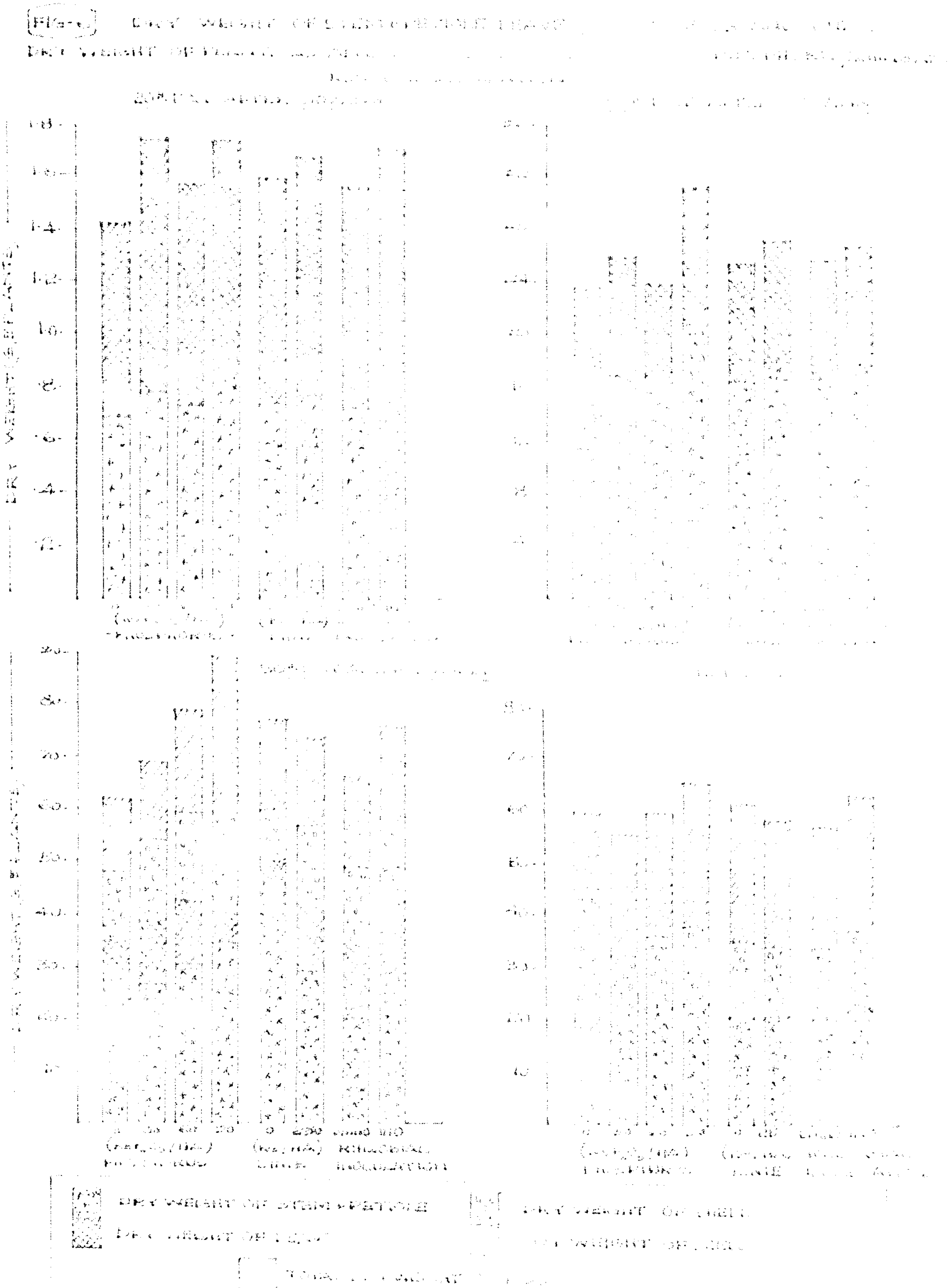
that of the control plot, but other levels followed a linear increase in dry matter with increasing levels of phosphorus.

Increase in dry weight of stem and petiole due to liming and inoculation was found to be marginal and non-significant.

Significant interaction effect was observed between phosphorus and liming on the 20th day. Phosphorus at 90 kg P_2O_5/ha in combination with 250 kg lime/ha gave maximum dry weight of stem + petiole and it was significantly higher than all other combinations except 30 kg P_2O_5 + 250 kg lime/ha. No phosphorus + 250 kg lime/ha recorded the least dry weight. Though the overall trend was in favour of positive interaction between phosphorus levels and liming, it was neither steady nor consistent.

Dry weight of stem + petiole went on increasing till the 80th day of plant growth but the same was found to decrease at harvest. Increase in dry weight over the stages was enhanced by higher dose of phosphorus.

Although the increase in dry weight of stem and


DRY WEIGHT OF

petiole was non-significant, there was an increasing trend with increasing dose of phosphorus fertilizer. Kesavan and Morachen (1973) also observed the same with regard to total dry matter of soybean plant, variety EC 39821.

Liming at 250 kg/ha was on par with the control. Same trend was noticed in the case of inoculation. However, limed plots and inoculated treatments had a slight edge over the control. The result will be discussed further subsequently while dealing with total dry weight of plants.

1.6 Dry weight of leaves.

Data on dry weight of leaves on 20th, 50th and 80th days after sowing are presented in Table 5 and Fig.6 and the analysis of variance is given in Appendix V.

Dry weight of leaves was not influenced by the levels of phosphorus on the 20th and 50th days but on the 80th day, there was significant increase with increasing levels of phosphorus. Although significant increase in dry weight of leaves was not obtained with increasing levels of phosphorus, there was an increase

Table 5. Effect of phosphorus nutrition, liming and rhizobial inoculation on the dry weight of leaves

TREATMENTS	Dry weight of leaves (g)		
	20th day after sowing	50th day after sowing	80th day after sowing
Levels of phosphorus ($Kg\ P_2O_5/ha$)			
0	0.836	8.491	11.03
30	0.965	8.648	12.29
60	0.833	8.484	12.91
90	0.915	10.310	17.11
F' test	NS	NS	Sig.
SEm ±	0.063	0.664	1.37
CD at 5%	-	-	3.95
Levels of lime (Kg/ha)			
0	0.862	8.974	13.55
250	0.913	8.970	13.11
F' test	NS	NS	NS
SEm ±	0.045	0.469	0.97
CD at 5%	-	-	-
Rhizobial inoculation			
Uninoculated	0.851	8.885	13.17
Inoculated	0.923	9.082	13.50
F' test	NS	NS	NS
SEm ±	0.045	0.469	0.97
CD at 5%	-	-	-

Table 5 a. Combined effect of phosphorus and liming on the dry weight of leaves (g/5 plants) on the 20th day after sowing

Levels of phosphorus ($Kg\ P_2O_5/ha$)	Levels of lime (Kg/ha)		Mean
	0	250	
0	0.834	0.838	0.836
30	0.907	1.022	0.965
60	0.960	0.705	0.833
90	0.745	1.085	0.915
Mean	0.862	0.913	0.888

SEm ± 0.089

CD at 5% 0.265

in mean dry weight from control to 90 kg P_2O_5/ha on the 50th day. On the 80th day, 90 kg P_2O_5/ha gave significant increase in dry weight of leaves over plots where phosphorus was applied at the rate of 0, 30 or 60 kg P_2O_5/ha.

Liming or inoculation did not affect the dry weight of leaves.

Interaction between phosphorus and liming on 20th day had significant effect on dry weight of leaves but the effects were limited to certain combinations only. Phosphorus at 90 kg P_2O_5/ha along with 250 kg lime/ha was significantly superior to 90 kg P_2O_5/ha without lime and 60 kg P_2O_5 + 250 kg lime/ha. Similar was the difference noted when 90 kg P_2O_5/ha without lime and 60 kg P_2O_5/ha was applied at 250 kg lime/ha level.

Dry weight of leaves increased from 20th day to 50th day with further increase at the third stage. Highest level of phosphorus gave the maximum increase in dry weight with advancement of crop growth.

Significant increase on the 80th day and increasing trend on 50th and 20th day in the dry weight of leaves due to increasing levels of phosphorus may be attributed to increased branching and leaf production as evidenced by higher leaf area index (Table 4).

The results will be further discussed under total dry weight of plants.

1.7 Dry weight of shell.

Data on the dry weight of shell are presented in Table 6 and Fig. 6 and the analysis of variance is given in Appendix IV.

Increasing levels of phosphorus had no significant effect on the dry weight of shell. Mean dry weight of shell on the 80th day was highest when 90 kg P_2O_5/ha was applied but at harvest stage, control gave the highest value.

Liming did not give any significant effect but the mean dry weight showed a negative effect with higher levels of liming. Although inoculation did not produce statistically significant results, an increasing trend was observed with inoculation. Interaction effect was not significant.

Table 6. Effect of phosphorus nutrition, liming and rhizobial inoculation on the dry weight of shell and seeds

TREATMENTS	Dry weight of shell(g)		Dry weight of seeds(g)	
	80th day after sowing	Harvest	80th day after sowing	Harvest
Levels of phosphorus ($Kg\ P_2O_5$/ha)				
0	13.00	14.81	14.30	24.37
30	14.99	13.26	15.42	23.22
60	16.14	13.78	19.80	23.49
90	17.98	14.24	19.85	27.93
F' test	NS	NS	NS	NS
SEm ±	1.44	1.53	2.04	3.34
CD at 5%	-	-	-	-
Levels of lime (Kg/ha)				
0	16.24	14.45	17.80	25.79
250	14.81	13.59	16.88	23.71
F' test	NS	NS	NS	NS
SEm ±	1.02	1.08	1.45	2.36
CD at 5%	-	-	-	-
Rhizobial inoculation				
Uninoculated	15.21	13.06	17.43	23.09
Inoculated	15.84	14.98	17.26	26.41
F' test	NS	NS	NS	NS
SEm ±	1.02	1.08	1.45	2.36
CD at 5%	-	-	-	-

Dry weight of shell fell at harvest stage from that on the 80[th] day.

Results will be discussed under the total dry weight of plants.

1.8 Dry weight of seeds.

Data on the dry weight of seeds are presented in Table 6 and Fig.6 and the analysis of variance is given in Appendix V.

Phosphorus levels could not influence dry weight of seeds significantly at any of the stages. At both the stages, 90 kg P_2O_5/ha gave higher dry weight but it was on par with other levels.

Control plot gave higher yield than plot applied with 250 kg lime/ha though differences were not significant statistically. No difference was noted with inoculation. Interaction had no significant effect.

Dry weight of seed increased from the 80[th] day to harvest stage of the crop.

1.9 Total dry weight of plants.

Data on the total dry weight of plants are

Table 7. Effect of phosphorus nutrition, liming and rhizobial inoculation on the total dry weight of plants

TREATMENTS	Total dry weight of plants (g)			
	20th day after sowing	50th day after sowing	80th day after sowing	Harvest
Levels of phosphorus ($Kg\ P_2O_5/ha$)				
0	1.151	23.70	62.18	66.80
30	1.747	26.00	69.23	55.32
60	1.568	24.04	79.27	59.44
90	1.765	31.07	90.27	65.68
F' test	NS	NS	NS	NS
SEm ±	0.105	2.14	7.36	6.60
CD at 5%	-	-	-	-
Levels of lime (Kg/ha)				
0	1.617	25.39	76.87	61.78
250	1.681	27.01	73.91	58.78
F' test	NS	NS	NS	NS
SEm ±	0.077	1.51	5.21	4.67
CD at 5%	-	-	-	-
Rhizobial inoculation				
Uninoculated	1.586	25.66	75.12	57.45
Inoculated	1.712	26.75	75.66	63.17
F' test	NS	NS	NS	NS
SEm ±	0.077	1.51	5.21	4.67
CD at 5%	-	-	-	-

Table 7 a. Combined effect of phosphorus and liming on the total dry weight of plants (g/5 plants) on the 20th day after sowing

Levels of phosphorus ($Kg\ P_2O_5/ha$)	Levels of lime (Kg/ha) 0	250	Mean
0	1.550	1.480	1.515
30	1.625	1.869	1.747
60	1.775	1.360	1.568
90	1.517	2.014	1.765
Mean	1.681	1.681	1.681

SEm ± 0.148

CD at 5% 0.428

presented in Table 7 and Fig. 6 and the analysis of variance is given in Appendix VI.

At none of the stages, viz: 20th, 50th, 80th days after sowing or at harvest, phosphorus, liming or inoculation could exert any influence on the dry weight of plants.

Interaction between phosphorus and liming was found to have significant influence on the dry weight, on the 20th day. Treatment of 90 kg P_2O_5/ha applied in combination with 250 kg lime/ha was significantly superior to the same dose of phosphorus without lime. The above treatment was also significantly superior to treatment combinations having 250 kg lime/ha with 0 or 30 kg P_2O_5/ha and to that of the control. Treatment combination 30 kg P_2O_5/ha + 250 kg lime/ha was significantly superior to combination 60 kg P_2O_5 + 250 kg lime/ha and was on par with others.

There was no consistent increase in dry matter accumulation by plant parts at any of the stage by application of phosphorus. Though an increasing trend was noticed almost in all the cases, it was most conspicuous in the case of dry weight of leaves, in which there was significant increase on the 80th day after sowing. These results also support the conclusion that the inherent phosphorus level of the soil is nearly at adequacy level. Liming and inoculation did not result in significant improvement in dry matter accumulation. The reasons for the lack of response have already been discussed. Many of the reported experimental results indicate significant increase of dry weight consequent to application of lime (Chew and Vivekanandan, 1975; Baumgartner et al. 1974; Elpete, 1972) and inoculation (Lufti and Petit, 1974; Chatterjee, et al., 1972).

The interaction between phosphorus and liming was significant in dry weight of leaves and total dry weight on the 20th day. Though the effect was not consistent, there was an indication of a positive response to the combined application of higher levels of phosphorus along with lime. However, the effects were not consistent even in this character.

Over the stages, there was a steady increase in dry weight of stem + petiole upto the 80th day, after which it showed a conspicuous decrease. A similar trend of decrease in dry weight after the 80th day was noticed in the case of total dry weight also. The dry weight of seed on the contrary, registered nearly 47.2% increase over the above stages. Part of the decrease in total dry weight and that of stem + petiole may be attributed to the leaf fall that occured after the 80th day. There could have been also translocation of carbohydrate to the developing seeds and this might have partly been responsible for the decrease in dry weight. This will be further substantiated by the fact that dry weight of shell also decreased from 80th day till harvest.

1.10 Number of root nodules.

Data on the number of root nodules are presented in Table 8 and the analysis of variance is given in Appendix VII.

On both 50th and 80th days after sowing, levels of phosphorus failed to produce significant effect on

Table 8. Effect of phosphorus nutrition, liming and rhizobial inoculation on the number of root nodules and fresh weight of root nodules per plant.

TREATMENTS	Number of root nodules		Fresh weight of root nodules (g)	
	50th day after sowing	80th day after sowing	50th day after sowing	80th day after sowing
Levels of phosphorus. ($Kg\ P_2O_5$/ha)				
0	0.030 (1.015)	0.000 (1.000)	0.006	0.000
30	0.223 (1.106)	0.121 (1.059)	0.016	0.020
60	0.092 (1.045)	0.098 (1.048)	0.010	0.007
90	0.416 (1.190)	0.418 (1.191)	0.026	0.061
F' test	NS	NS	NS	NS
SEm ±	0.055	0.063	0.009	0.018
CD at 5%	-	-	-	-
Levels of lime (Kg/ha)				
0	0.126 (1.061)	0.090 (1.044)	0.013	0.015
250	0.248 (1.117)	0.221 (1.105)	0.015	0.028
F' test	NS	NS	NS	NS
SEm ±	0.039	0.045	0.006	0.013
CD at 5%	-	-	-	-
Rhizobial inoculation				
Uninoculated	0.192 (1.092)	0.075 (1.037)	0.012	0.011
Inoculated	0.179 (1.086)	0.237 (1.112)	0.017	0.033
F' test	NS	NS	NS	NS
SEm ±	0.039	0.045	0.006	0.013
CD at 5%	-	-	-	-

Figure in paranthesis indicate root (x + 1) transformed values.

number of nodules. But, increasing levels of phosphorus showed an increasing trend in the number of nodules except 30 kg P_2O_5/ha which recorded higher nodules than 60 kg P_2O_5/ha.

Liming at 250 kg/ha was on par with the control. Same was the trend obtained for inoculation. Interaction effect due to various combinations did not show any significance.

Literature on the effect of applied phosphorus (Jones et al. 1977; Bebin and Ignatenko, 1969) and lime (Blevins et al. 1977; Martini et al. 1974; Chew and Vivekanandan 1975) on legumes generally indicate increased nodulation consequent to their application. The lack of significant increase in nodulation in the present study thus indicates that the levels of phosphorus and calcium in the soil were adequate for maintaining nodulation at the optimum level. Similarly, there was no response to rhizobium inoculation indicating that the effective strains of *Rhizobium japonicum* were also available in the soil originally. Literature on this aspect also, generally, indicates enhanced nodulation because of artificial culture inoculation

(Katti *et al.* 1970; Jansenvian *et al.* 1976; Konova *et al.* 1976; Singh and Saxena, 1977). According to Konova *et al.* (1976), nodulation in legumes is induced by the presence of effective strains of the appropriate Rhizobium species. In general, the number of nodules increases in proportion to the number of such organisms present in the soil upto a limit. The lack of significant increase in nodulation, thus indicates that adequate number of such organism was originally present in the soil. According to Jansenvian *et al.* (1976) a conspicuous increase in nodulation in soybean was observed in fields where it had not been cultivated when artificial inoculation is resorted to. A similar result was expected in the present study also as the field was never under the crop before. It may however be noted that cowpea also comes under the same cross inoculation group as soybean and probably, the strain effective on cowpea was already available in the soil. In a similar study on the effectiveness of culture inoculations on soybean conducted in 1978 (Nair, 1978) on a similar type of soil it was found that there was a significant decrease in nodulation and yield when culture inoculation was done. It was indicated from this study that the native strains were effective on soybean also and that these natural strains were more effective than the introduced ones. Though in the present study, the effect of inoculation was not significant, the mean nodule number of the inoculated set was less than the uninoculated control on the 50th day after sowing. The results may thus be summarised as follows. (i) There was abundance of effective strains of Rhizobium japonicum originally in the soil (ii) The introduced strains were only as effective or even inferior to the native strains.

1.11 Weight of nodules.

Data on the fresh weight of root nodules are presented in Table 8 and the analysis of variance is given in Appendix VII.

None of the treatments was effective in raising the weight of nodule significantly. Levels of phosphorus, liming and inoculation gave no significant effect on the weight of nodules.

Significant interaction effect was not observed among any of treatment combinations.

The results reported on the effect of phosphorus, liming and inoculation generally indicate a positive response of these treatments on nodule weight. In the experiment under report, there was no significant effect of these treatments on this character. The reasons for such an observations were discussed already while dealing with the observation on nodule number.

2. Yield and Yield Attributes:

2.1 Number of pods per plant.

Data on the number of pods per plant are presented in Table 9 and the analysis of variance is given in Appendix VIII.

Number of pods per plant could not be affected by any of the treatments. The interaction was also not significant.

Saleh (1976) reported increase in the number of pods per plant when phosphorus was applied. The results show that the number of pods is a character that is affected by application of phosphorus in deficient soils. The absence of a significant increase in the number of pods per plant in this study indicates that

Table 9. Effect of phosphorus nutrition, liming and rhizobial inoculation on number of pods per plant, number of seeds per pod, weight of seeds per pod and test weight

TREATMENTS	No. of pods/ plant	No. of seeds/ pod	Weight of seeds/pod (g)	Test weight (g) 1000 seeds
Levels of phosphorus ($Kg\ P_2O_5$/ha)				
0	30.81 (5.55)	2.353 (1.534)	2.579	94.60
30	24.77 (4.98)	2.374 (1.541)	2.488	96.35
60	29.93 (5.47)	2.152 (1.467)	2.349	96.35
90	28.90 (5.38)	2.223 (1.491)	2.792	96.58
F' test	NS	NS	NS	NS
SEm ±	0.297	0.032	0.324	1.76
CD at 5%	-	-	-	-
Levels of lime (Kg/ha)				
0	28.29 (5.32)	2.295 (1.515)	2.628	94.58
250	28.83 (5.37)	2.253 (1.501)	2.475	96.43
F' test	NS	NS	NS	NS
SEm ±	0.210	0.020	0.228	1.24
CD at 5%	-	-	-	-
Rhizobial inoculation				
Uninoculated	26.47 (5.15)	2.259 (1.503)	2.380	97.13
Inoculated	30.72 (5.54)	2.292 (1.514)	2.724	93.88
F' test	NS	NS	NS	NS
SEm ±	0.210	0.020	0.228	1.24
CD at 5%	-	-	-	-

Figure in parenthesis indicate root (x) transformed values the supply of phosphorus was adequate in the soil originally. Similar results of lack of significant increase in pod number were also reported by Sable and Khuspe (1977). It may be noted that in this experiment, there was no increase in final yield also.

Sable and Khuspe (1977) reported an increase in the number of pods per plant when culture inoculation was resorted to, persumably through the increased nitrogen supply because of enhanced symbiotic nitrogen fixation. In the present study, there was no response to inoculation. Similarly, there was no increase in the number of pods when liming was done.

2.2 Number of seeds per pod.

Data on the number of seeds per pod are presented in Table 9 and the analysis of variance is given in Appendix VIII.

Levels of phosphorus did not influence the character significantly. Liming and rhizobial inoculation also did not produce significant effect. Interaction was also nonsignificant.

The reasons for the lack of response to applied phosphorus, liming and inoculation have been discussed earlier while dealing with the vegetative characters. The same reasons will be applicable in this case also.

2.3 Weight of seeds per pod.

Data on the weight of seeds per pod are presented in Table 9 and the analysis of variance is given in Appendix VIII.

The data reveal that levels of phosphorus, liming and rhizobial inoculation did not exert any significant effect. There was no significant interaction effects.

The total weight of seeds per pod is a function of the number of seeds per pod and the test weight. It may be noted that these characters were not significantly affected by the various treatments.

2.4 Test weight.

Data are presented in Table 9 and the analysis of variance is given in Appendix IX.

All the levels of phosphorus, liming and rhizobial inoculation were on par statistically. Interaction effects were also nonsignificant.

Results of the experiment by Sable and Khuspe (1977) have indicated increase in test weight of soybean with increasing levels of phosphorus. Similar increase in the weight of seeds because of culture inoculation was reported by Sable and Khuspe (1977) and Konova _et al_. (1976). These results indicate that test weight is a character that can be altered substantially by phosphorus and nitrogen supply. The fact that there was no response to phosphorus, liming and culture inoculation in this study again indicates that both the supply of phosphorus and calcium was adequate in the soil and that culture inoculation did not alter the nitrogen supply to the crop.

2.5 Shelling percentage.

Data on the shelling percentage are presented in Table 10 and the analysis of variance is given in Appendix IX.

Levels of phosphorus, liming and rhizobial inoculation could not exert any significant change on

Table 10. **Effect of phosphorus nutrition, liming and rhizobial inoculation on shelling percentage, harvest index and moisture percentage of seeds**

TREATMENTS	Shelling percentage: 80th day after sowing	Shelling percentage: Harvest	Harvest index	Moisture percentage of seeds
Levels of phosphorus ($Kg\ P_2O_5/ha$)				
0	47.92 (43.81)	62.94 (52.51)	0.473	6.12 (14.32)
30	49.92 (44.95)	63.29 (52.71)	0.466	6.06 (14.25)
60	54.06 (47.33)	63.90 (53.07)	0.484	5.90 (14.06)
90	50.21 (45.12)	65.37 (53.95)	0.446	6.28 (14.52)
F' test	NS	NS	NS	NS
SEm ±	1.33	0.61	0.009	0.29
CD at 5%	-	-	-	-
Levels of lime (Kg/ha)				
0	49.35 (44.63)	64.78 (53.01)	0.466	6.23 (14.46)
250	51.69 (45.97)	63.96 (53.11)	0.469	5.95 (14.12)
F' test	NS	NS	NS	NS
SEm ±	0.94	0.43	0.006	0.21
CD at 5%	-	-	-	-
Rhizobial inoculation				
Uninoculated	50.94 (45.54)	63.98 (53.12)	0.467	6.00 (14.18)
Inoculated	50.14 (45.06)	63.78 (53.00)	0.468	6.18 (14.40)
F' test	NS	NS	NS	NS
SEm ±	0.94	0.43	0.006	0.21
CD at 5%	-	-	-	-

Figure in parenthesis indicate values after making angular transformation.

Table 10 a. Combined effect of phosphorus and liming on shelling percentage on the 80th day after sowing

Levels of phosphorus ($Kg\ P_2O_5$/ha)	Levels of lime (Kg/ha) 0	250	Mean
0	44.41 (41.79)	51.46 (45.84)	47.92 (43.81)
30	48.15 (43.94)	51.68 (45.97)	49.92 (44.95)
60	49.55 (44.74)	58.52 (49.91)	54.06 (47.33)
90	55.36 (48.08)	45.04 (42.16)	50.21 (45.12)
Mean	49.35 (44.63)	51.69 (45.97)	50.52 (45.30)

SEm ± 1.883

CD at 5% 5.436

the shelling percentage either on the 80^{th} day after sowing or at harvest.

Interaction between phosphorus and liming on 80^{th} day was found to be significant. Phosphorus level at 60 kg P_2O_5/ha in combination with 250 kg lime/ha gave the highest shelling percentage which was significantly higher than phosphorus at 90 kg P_2O_5 + 250 kg lime/ha, 30 kg P_2O_5/ha + no lime and the control. Combination of 90 kg P_2O_5/ha without lime was also found to be significantly superior to the treatment of 90 kg P_2O_5 + 250 kg lime/ha and to that of the control. The differences between the other treatment combinations were not significant.

There was a marked increase in shelling percentage from the 80^{th} day till harvest. Most of this increase must be attributed to the increase in seed weight with advancing age. However, the decrease in the weight of shell (Table 6) also contributed partly to the increase in shelling percentage. The reasons attributed to the lack of significant increase in other yield components consequent to application of phosphorus, lime and culture inoculation are applicable in this case also. Though the interaction between phosphorus and liming was significant, the results were not consistent.

2.6 Harvest index.

Data on the harvest index are presented in Table 10 and the analysis of variance is given in Appendix IX.

None of the treatments could influence harvest index significantly. Interaction effects were also nonsignificant.

Phosphorus is generally considered to be a nutrient that increases the yield of grain at the expense of vegetative growth and increased nitrogen supply usually increases the vegetative growth at the expense of grain yield. It was therefore originally expected that phosphorus application would increase the harvest index and inoculation would decrease it. In this study, there was neither response to applied P nor to culture inoculation. Similarly, application of lime also did not influence harvest index significantly. The reasons for such results have been discussed already. It may also be noted that these treatments could not alter the vegetative growth and the final yield of grain and stover significantly.

2.7 Moisture percentage of seeds.

Data on the moisture percentage of seeds are presented in Table 10 and the analysis of variance is given in Appendix IX.

The results reveal that phosphorus, liming and inoculation did not exert any significant effect on this character. Interactions also did not have any significant effect.

Moisture content of seed is usually considered to be a character either indicative of difference in the chemical composition of seeds or degree of maturity. The study indicates that these components were not altered by the different treatments. Visual observations on the maturity of the crop also did not show any difference between treatments. One of the objectives of recording the moisture content of seeds was to adjust the seed yield of the net plot to a uniform moisture content. As the data showed no difference in moisture percentage such an adjustment was not done. It may also be pointed out in this connection that the produce was sun-dried for 3 days prior to collection of samples for moisture determination and also recording the yield. Such long period of sun-drying might have masked the differences in seed moisture content, if at all it was present at the time of harvest.

2.8 Grain yield.

Data on the grain yield are presented in Table 11 and Fig. 7 and the analysis of variance is given in Appendix VIII.

There was no significant increase in yield due to application of phosphorus but the results reveal that there was an increasing trend in yield with increasing levels of applied phosphorus.

Limed plots had slight advantage over the control plot but inoculation was found to have negative effect on the yield although the effect was not significant. Interaction effects were not significant.

The results of a non-significant effect of graded levels of phosphorus is in agreement with the trend

Table 11. Effect of phosphorus nutrition, liming and rhizobial inoculation on the yield of grain and yield of stover

TREATMENTS		Yield (Kg/ha)	
		Grain	Stover
Levels of phosphorus ($Kg\ P_2O_5/ha$)			
	0	2127.72	2356.68
	30	2216.01	2559.74
	60	2365.51	2519.13
	90	2379.05	2957.62
F' test		NS	Sig.
SEm ±		94.76	117.72
CD at 5%		-	322.22
Levels of lime (Kg/ha)			
	0	2253.09	2589.76
	250	2290.76	2606.83
F' test		NS	NS
SEm ±		67.10	89.99
CDat 5%		-	-
Rhizobial inoculation			
Uninoculated		2335.49	2668.04
Inoculated		2208.36	2528.55
F' test		NS	NS
SEm ±		67.10	89.99
CDat 5%		-	-

noticed in the case of yield components. There was also no consistent improvement in growth of the plant as indicated by the results on growth characters like plant height, number of branches and by the data on dry weight of the plant components. A probable indirect advantage due to application of phosphatic fertilizer was thought to be the enhanced nodulation and consequent nitrogen nutrition of the crop. As the data on nodulation and nodule weight indicate, there was again no improvement in these characters also because of phosphorus supply. Another probable effect of phosphorus on nitrogen fixation could be an increased efficiency of the nodules to fix nitrogen. The data on the content and uptake of nitrogen by soybean indicate that there was no such effect noticed. All these point to the fact that the availability of phosphorus in the soil on which the experiment was conducted was adequate enough both in terms of requirement of phosphorus for the growth of the crop directly and also in terms of requirement for effective nodulation and nitrogen fixation.

A number of references are available in literature showing increase in yield of soybeans consequent to phosphatic fertilizer application (Dutra et al., 1975; Kesavan and Morachan, 1973; Ferrari et al 1976; Tomar and Dev, 1973; Chatterjee et al., 1972b and Chesney, 1979). There are also a few reported results in which there was no increase in yield because of phosphorus application (Mascarenhas and Kilhal, 1974; Sable and Khuspe, 1976).

As in the case of phosphorus, a favourable response was also expected from application of lime. This was especially so because the soil is acidic. It is known that the calcium level in the soil, optimum for the growth of legumes is generally higher than that of the non-legumes. This is reported to be because of the higher cation exchange capacity of legume roots (Tisdale and Nelson, 1971) and the higher calcium requirement for nodulation (Lowther and Loneragan, 1968). In the present investigation, there was no significant increase in yield because of application of lime. The results on yield components, growth characters and dry weight were also similar. Again, in the case of nitrogen uptake also, there was no significant improvement because of application of lime.

The only explanation for such a behaviour appears to be the fact that at least for this variety of soybean the soil supply of calcium was adequate enough both directly in terms of nutrition of the crop and also for effective nitrogen fixation. As in the case of phosphorus, most of the reported experimental results reveal advantage due to liming (Ferrari, 1976; Martini et al., 1974; Peey et al., 1969; and Mascarenhas et al., 1969).

Culture inoculation did not result in a significant increase in yield. On the contrary, the mean yield of the inoculated series was slightly lower than the uninoculated set. The mean yield of the crop was fairly high and was comparable to the yield figure reported in literature. Such a result points to the fact that the crop did not suffer for want of nitrogen symbiotically fixed. There was also no visual symptom of nitrogen starvation of the crop. The data on nodule number and weight will also substantiate the point that inoculation was not beneficial. The explanation for such a result lies in the fact that, in all probability, the soil originally had adequate

Table 11 a. Combined effect of phosphorus and rhizobial inoculation on stover yield (Kg/ha).

Levels of phosphorus ($Kg\ P_2O_5/ha$)	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	2504.41	2208.95	2356.68
30	2884.05	2235.43	2559.74
60	2474.99	2563.27	2519.13
90	2808.71	3107.12	2957.62
Mean	2589.76	2606.83	2598.30

SEm ± 167.75

CD at 5% 482.64

number of strains of *Rhizobium japonicum* effective on soybean. In a similar experiment conducted earlier in the same type of soil, there was a significant decrease in yield, nodulation and nitrogen uptake of soybean when culture inoculation was done (Nair, 1978). It was concluded from the results that there was not only adequate number of effective strains of rhizobial species but also that the strains introduced through the culture were less effective on soybean. Though in the present study, the decrease in yield consequent to culture inoculation was not significant, there was decrease in mean yield consequent to culture inoculation. However, literature on the subject in general indicates improvement in the performance of the crop when inoculation was done (Chatterjee et al., 1972a; Pevy et al., 1969; Katti et al., 1970; Sable and Khuspe, 1977).

2.9 Stover yield.

Data on the stover yield are presented in Table 11 and Fig. 7 and the analysis of variance is given in Appendix VIII.

Levels of phosphorus had significant effect on the stover yield. Highest level of phosphorus at 90 kg P_2O_5/ha was significantly superior to all other lower levels. Although 30 kg and 60 kg P_2O_5/ha were found to be better, it was not significantly superior to the control. Neither liming nor rhizobial inoculation could affect the yield of stover significantly.

Interaction between phosphorus and rhizobial inoculation was found to be significant. Inoculation when combined with phosphorus at the rate of 90 kg P_2O_5/ha, was significantly superior to other doses of phosphorus along with culture treatment. The above treatment combination was also superior to treatment of 60 kg P_2O_5/ha applied without inoculation. Treatment combinations of 30 kg P_2O_5/ha or 90 kg P_2O_5/ha without inoculation were found to be significantly superior to treatments 0 or 30 kg P_2O_5/ha with inoculation.

Contrary to the result of the effect of phosphorus on grain yield, vegetative characters and dry weight, there was a significant increase in the yield of stover at the highest level of applied phosphorus (90 kg P_2O_5/ha). Such a statistically significant increase in yield of stover without there being a similar response in the case of vegetative characters is difficult to explain. The only justification for this probably lies in the fact that the cumulative, though non-significant improvement in growth parameters manifested itself on the final yield of stover. It may be noted here that the variability in the observations on characters like height, number of branches, leaf area, dry weight etc. might have been comparatively higher because the sample size was small.

As in the case of grain yield and other characters, there was no significant response to liming and inoculation. In the case of the latter, the mean yield of the inoculated set was even lower than the uninoculated series. The reasons for such a result have been discussed in detail earlier.

The interaction between phosphorus and inoculation was significant. However, the results are inconsistent and difficult to explain. The significant increase noted in some combinations may

Table 12. Effect of phosphorus nutrition, liming and rhizobial inoculation on nitrogen content of stem and petiole

TREATMENTS	Nitrogen content of stem & petiole(%)			
	20th day after sowing	50th day after sowing	80th day after sowing	Harvest
Levels of phosphorus ($Kg\ P_2O_5/ha$)				
0	2.121	1.249	0.641	0.441
30	1.662	1.190	0.743	0.552
60	1.911	1.193	0.555	0.695
90	2.252	1.194	0.666	0.545
F' test	Sig.	NS	NS	NS
SEm ±	0.138	0.071	0.084	0.071
CD at 5%	0.395	-	-	-
Levels of lime (Kg/ha)				
0	2.013	1.217	0.672	0.563
250	1.960	1.196	0.630	0.554
F' test	NS	NS	NS	NS
SEm ±	0.095	0.045	0.055	0.045
CD at 5%	-	-	-	-
Rhizobial inoculation				
Uninoculated	2.075	1.172	0.682	0.567
Inoculated	1.898	1.240	0.621	0.550
F' test	NS	NS	NS	NS
SEm ±	0.095	0.045	0.055	0.045
CD at 5%	-	-	-	-

therefore treated as a resultant of chance errors.

3. Chemical Analyses of Plant

3.1 Total nitrogen content in different components.

3.1.1 Nitrogen content of stem and petiole.

Data on the nitrogen content of stem and petiole are presented in Table 12 and Fig.8 and analysis of variance in Appendix X.

Application of phosphorus at the highest level of 90 kg P_2O_5/ha gave the highest percentage of nitrogen on the 20th day after sowing which was significantly superior to 30 kg P_2O_5/ha but was at par with other doses of phosphorus. However, control plot also recorded significantly higher content of nitrogen than where phosphorus was applied at 30 kg P_2O_5/ha. On the 50th day, 80th day and at harvest differences in nitrogen content were not significant. However, the general trend shows an increase in nitrogen content with increasing levels of phosphorus.

Liming or rhizobial inoculation could not affect nitrogen content significantly. No interactions were significant.

Table 13. Effect of phosphorus nutrition, liming and rhizobial inoculation on the nitrogen content of leaves

TREATMENTS		Nitrogen content leaves (%)		
		20th day after sowing	50th day after sowing	80th day after sowing
Levels of phosphorus ($Kg\ P_2O_5/ha$)				
	0	4.166	3.405	2.395
	30	3.920	3.277	2.437
	60	4.045	3.260	2.426
	90	4.215	3.451	2.415
F' test		NS	NS	NS
SEm ±		0.158	0.155	0.130
CD at 5%		-	-	-
Levels of lime (Kg/ha)				
	0	4.073	3.277	2.341
	250	4.100	3.420	2.495
F' test		NS	NS	NS
SEm ±		0.114	0.110	0.089
CD at 5%		-	-	-
Rhizobial inoculation				
Uninoculated		4.113	3.384	2.492
Inoculated		4.060	3.313	2.344
F' test		NS	NS	NS
SEm ±		0.114	0.110	0.089
CD at 5%		-	-	-

Percentage nitrogen content was maximum in the first stage which decreased markedly with advancement of crop growth.

The results will be discussed later while dealing with the nitrogen content of seeds.

3.1.2 Nitrogen content of leaves.

Data on the nitrogen content of leaves are presented in Table 13 and Fig.8 and the analysis of variance in Appendix XI.

Levels of phosphorus, liming and rhizobial inoculation did not produce any significant effect on the nitrogen content of leaves on 20th, 50th or 80th days after sowing. There was no significant interaction between phosphorus, liming and rhizobial inoculation.

Percentage of nitrogen in this part also tended to decrease with advancement of growth.

Discussion on this also will be covered subsequently.

3.1.3 Nitrogen content of shell.

Data on the nitrogen content of shell are presented in Table 14 and Fig.8 and analysis of variance is given in Appendix X.

Table 14. Effect of phosphorus nutrition, liming and rhizobial inoculation on the nitrogen content of shell and seeds.

TREATMENTS		Nitrogen content (%)			
		Shell		Seeds	
		80th day after sowing	Harvest	80th day after sowing	Harvest
Levels of phosphorus ($Kg\ P_2O_5/ha$)					
	0	1.197	0.695	5.134	5.175
	30	1.177	0.722	4.993	5.460
	60	1.079	0.768	5.518	5.219
	90	1.123	0.901	5.450	5.310
F'test		NS	NS	NS	NS
SEm ±		0.095	0.063	0.167	0.214
CD at 5%		-	-	-	-
Levels of lime (Kg/ha)					
	0	1.170	0.762	5.315	5.205
	250	1.118	0.781	5.233	5.377
F' test		NS	NS	NS	NS
SEM ±		0.071	0.045	0.118	0.152
CD at 5%		-	-	-	-
Rhizobial inoculation					
Uninoculated		1.134	0.780	5.130	5.330
Inoculated		1.154	0.763	5.417	5.251
F' test		NS	NS	NS	NS
SEm ±		0.071	0.045	0.118	0.152
CD at 5%		-	-	-	-

Table 14 a. Combined effect of liming and rhizobial inoculation on the nitrogen content (%) of shell at harvest.

Levels of lime (Kg/ha)	Rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	0.658	0.875	0.772
250	0.901	0.661	0.781
Mean	0.780	0.773	0.777

SEm ± 0.063

CD at 5% 0.191

Different levels of phosphorus could not influence the nitrogen content of shell significantly. Liming and rhizobial inoculation also failed to exert significant effect.

Interaction between liming and rhizobial inoculation was significant at harvest stage. Uninoculated set where 250 kg lime/ha was applied recorded the maximum nitrogen content in shell which was significantly superior to the treatment with inoculation at the same level of lime and also to control. Inoculated set with no lime applied registered significantly higher content than both control and treatment with inoculation at 250 kg lime/ha.

Percentage nitrogen in shell was generally less at harvest stage than at the 80th day after sowing.

The result will be discussed subsequently.

3.1.4 Nitrogen content of seeds.

Data on the nitrogen content of seeds are presented in Table 14 and Fig. 8 and the analysis of variance in Appendix XI.

Levels of phosphorus did not have any significant effect on nitrogen content. Liming and rhizobial inoculation also failed to exert any influence on seed nitrogen content either on the 80th day or at harvest. There was no significant interaction effect between phosphorus, liming or rhizobial inoculation.

Percentage nitrogen in seed did not differ much between the two stages, namely 80th day and harvest.

The variation in nitrogen content of seeds was not significant either in the case of phosphorus, liming or inoculation. The results on the nitrogen content of stem + petiole, leaves and shell are also similar excepting in the case of stem + petiole at the first stage of observation, 20th day after sowing when there was significant effect of phosphorus. Again, in the case where the effect is significant, the results are not consistant enough to draw out valid conclusions. The general trend of the effect of phosphorus on nitrogen content may thus be taken to be that of a non-significant difference. The review on this aspect generally indicates an increase in nitrogen and protein content of seeds at higher levels of applied phosphorus, probably as a result of increased nodulations and nodule efficiency (Kapoor and Gupta, 1977). In the present study, there was virtually no indication of such a beneficial effect of phosphorus. These results also support the conclusion drawn earlier that the inherent phosphorus supplying power of the soil was well beyond the optimum level.

Similar to the effect of phosphorus, the effect of liming and inoculation are also generally reported to be favourable in terms of nitrogen content of grains in soybean (Kanki _et al._, 1974; Baumgartner _et al._, 1974; Chatterjee _et al._, 1972a,b; Sokorenko 1971; Sable and Khuspe, 1977). As in the case of other observations, there was no significant effect of either of the above treatments on the nitrogen content of seeds or of the other plant parts. The reason for such results have been already discussed.

Comparing between the stages, there was a marked decline in nitrogen content of stem + petiole, leaves and shell. The mean nitrogen content of stem + petiole decreased from 1.987 per cent to 0.559 per cent from

Table 15. Effect of phosphorus nutrition, liming and rhizobial inoculation on the uptake of nitrogen by stem and petiole

TREATMENTS	Uptake of nitrogen by stem and petiole (Kg/ha)			
	20th day after sowing	50th day after sowing	80th day after sowing	Harvest
Levels of phosphorus ($Kg\ P_2O_5/ha$)				
0	1.278	17.391	13.848	7.677
30	1.142	18.107	18.052	10.917
60	1.223	16.900	15.679	13.360
90	1.549	22.070	20.524	12.200
F' test	NS	NS	NS	NS
SEm ±	0.130	2.330	2.381	1.716
CD at 5%	-	-	-	-
Levels of lime (Kg/ha)				
0	1.297	17.985	17.572	11.998
250	1.299	19.253	16.479	10.079
F' test	NS	NS	NS	NS
SEm ±	0.095	1.648	2.037	1.213
CD at 5%	-	-	-	-
Rhizobial inoculation				
Uninoculated	1.319	17.810	17.718	10.597
Inoculated	1.277	19.420	16.339	11.480
F' test	NS	NS	NS	NS
SEm ±	0.095	1.648	2.037	1.213
CD at 5%	-	-	-	-

20th day after sowing to the harvest stage. The similar figures for leaves from 20th to 80th day are 4.087 per cent and 2.418 per cent. In the case of shell, the nitrogen content dropped from 2.144 per cent on the 80th day to 0.777 per cent at harvest. In the case of grains on the contrary, nitrogen content remained more or less the same from 80th day till harvest. One of the reasons for the marked decline in nitrogen content of all the plant parts (excepting grain) could be the dilution of nitrogen in a larger bulk of dry matter as the plants developed. But a dominant reason for such a decrease should be the translocation of this nutrient to the developing grains. This will become clear while comparing the nitrogen accumulation of different plant parts.

3.2 Uptake of nitrogen by different components.

3.2.1 Uptake of nitrogen by stem and petiole.

Data onthe uptake of nitrogen by stem and petiole are presented in Table 15, Fig. 9 and the analysis of variance is given in Appendix XII.

Application of different levels of phosphorus

Table 16. Effect of phosphorus nutrition, liming and rhizobial inoculation on the uptake of nitrogen by leaves

TREATMENTS	Uptake of nitrogen by leaves (Kg/ha)		
	20th day after sowing	50th day after sowing	80th day after sowing
Levels of phosphorus ($Kg\ P_2O_5/ha$)			
0	3.122	26.239	24.542
30	3.181	25.318	27.874
60	3.063	22.533	28.547
90	3.565	31.592	38.925
F' test	NS	NS	NS
SEm ±	0.310	3.092	4.152
CD at 5%	-	-	-
Levels of lime (Kg/ha)			
0	3.123	26.472	29.382
250	3.343	26.369	30.562
F' test	NS	NS	NS
SEm ±	0.219	2.185	2.936
CD at 5%	-	-	-
Rhizobial inoculation			
Uninoculated	3.093	25.800	30.495
Inoculated	3.373	27.041	29.450
F' test	NS	NS	NS
SEm	0.219	2.185	2.936
CD at 5%	-	-	-

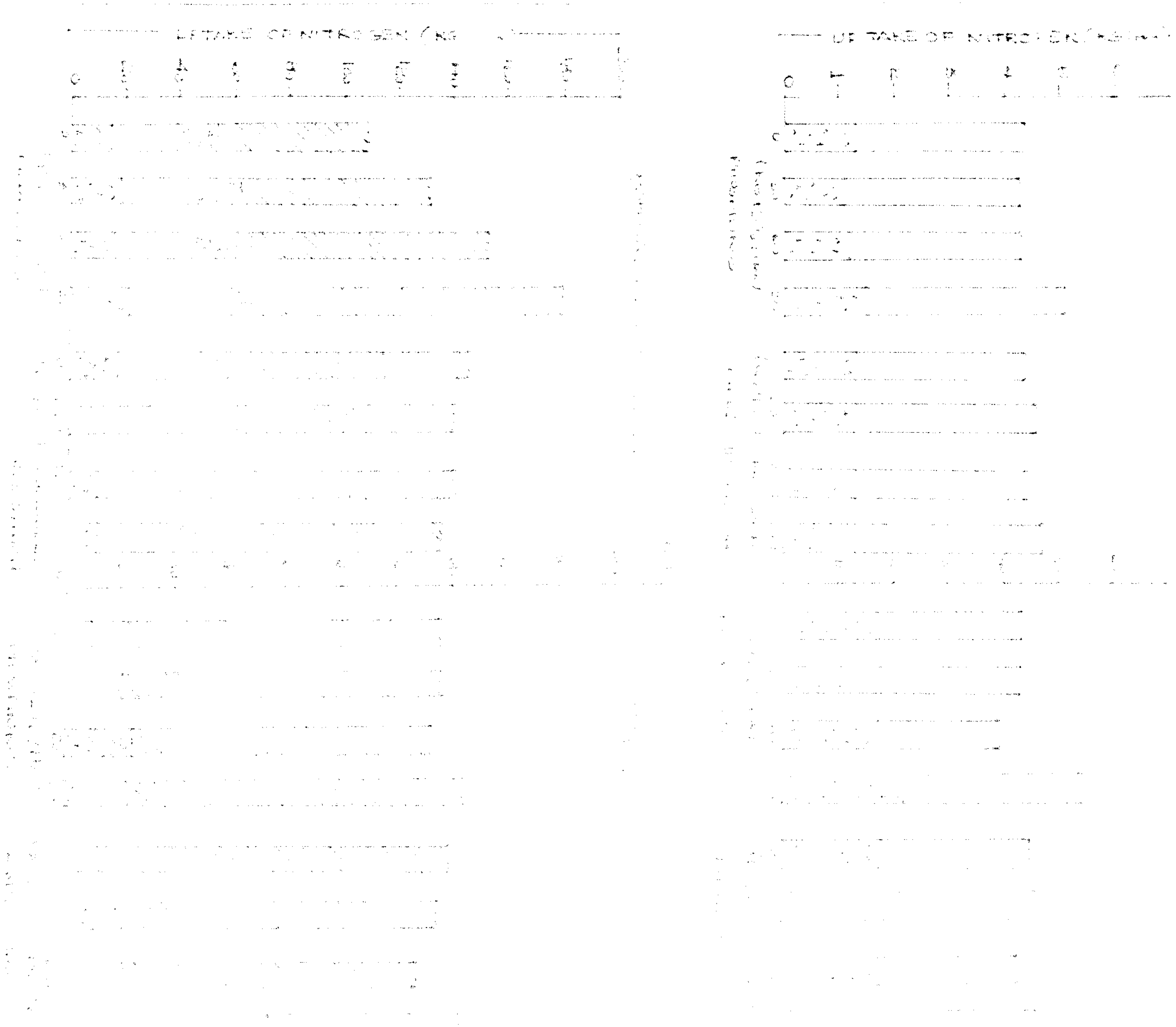


FIG. 9

did not have any significant effect on the uptake of nitrogen by stem and petiole. However, the highest level of 90 kg P_2O_5/ha recorded the maximum uptake of nitrogen on 20th, 50th and 80th days after sowing. On the other hand, uptake was minimum in the control treatment in all the above stages and also at harvest.

Neither levels of liming nor inoculation could bring about significant difference in the uptake of nitrogen at any of the stages namely 20th, 50th, 80th day after sowing or at harvest. Interaction effects were also non-significant.

Phosphorus application had no effect either on the nitrogen content or on dry weight of stem and petiole. Same was the effect noted with liming and inoculation. This is obviously reflected in the case of nitrogen uptake by stem and petiole.

The results on uptake of nitrogen by these plant parts will be discussed later.

3.2.2 Uptake of nitrogen by leaves.

Data on the uptake of nitrogen by leaves are presented in Table 16 and Fig.9 and the analysis of variance is given in Appendix XIII.

Significant difference in uptake was not observed with different levels of phosphorus, liming or rhizobial inoculation. However, a slight increase could be found when 90 kg P_2O_5/ha was applied, over the treatment receiving no phosphorus, at all three stages of growth, 20th, 50th and 80th days after sowing.

Between the stages, there was increase in the uptake of phosphorus, it being most conspicuous between 20th and 80th days after sowing. Between the 50th and 80th days, the increase in uptake was only marginal.

The data on the uptake of nitrogen by leaves also will be discussed later.

3.2.3 Uptake of nitrogen by shell.

Data on the uptake of nitrogen by shell on the 80th day after sowing and at harvest are presented in Table 17 and Fig.9 and the analysis of variance is given in Appendix XII.

The data reveal the absence of significant difference between varying levels of phosphorus, liming and rhizobial inoculation both on the 80th day and at harvest.

Table 17. Effect of phosphorus nutrition, liming and rhizobial inoculation on the uptake of nitrogen by shell and seeds

TREATMENTS	Uptake of nitrogen (Kg/ha)			
	Shell		Seed	
	80th day after sowing	Harvest	80th day after sowing	Harvest
Levels of phosphorus ($Kg\ P_2O_5/ha$)				
0	14.949	9.010	55.958	120.103
30	16.665	8.646	69.630	116.285
60	16.207	8.892	93.275	111.092
90	20.270	9.409	101.413	123.630
F' test	NS	NS	Sig.	NS
SEm ±	2.635	1.189	10.049	17.458
CD at 5%	-	-	29.020	-
Levels of lime (Kg/ha)				
0	18.450	9.181	81.555	118.283
250	15.595	8.797	78.582	117.272
F' test	NS	NS	NS	NS
SEm ±	1.863	0.841	7.106	12.345
CD at 5%	-	-	-	-
Rhizobial inoculation				
Uninoculated	16.993	8.455	82.160	110.851
Inoculated	17.052	9.523	77.978	124.703
F' test	NS	NS	NS	NS
SEm ±	1.863	0.841	7.106	12.345
CD at 5%	-	-	-	-

Table 17 a. Combined effect of phosphorus and liming on the uptake of nitrogen by seeds (Kg/ha) on the 80th day after sowing

Levels of phosphorus ($Kg\ P_2O_5/ha$)	Levels of lime (Kg/ha)		Mean
	0	250	
0	45.415	66.501	55.958
30	62.885	76.376	69.630
60	88.248	98.301	93.275
90	129.675	73.151	101.413
Mean	81.555	78.582	80.069

SEm ± 14.212

CD at 5% 41.041

There was no significant interaction effect between phosphorus, liming and inoculation.

From 80th day till harvest, there was a conspicuous decrease with the nitrogen uptake of shell in all the treatments, the overall mean percentage decrease being 52.8.

5.3.4 Uptake of nitrogen by seeds.

Data on the uptake of nitrogen by seeds are presented in Table 17 and Fig.9 and the analysis of variance is given in Appendix XIII.

Levels of phosphorus exerted significant effect on the uptake of nitrogen by seeds on the 80th day after sowing but did not have such an effect at harvest stage. Highest phosphorus level at 90 kg P_2O_5/ha gave the highest uptake value which decreased at lower levels of phosphorus. Phosphorus at the rates of 60 and 90 kg P_2O_5/ha were significantly superior to control and 30 kg P_2O_5 level.

Liming and rhizobial inoculation did not have significant effect on nitrogen uptake either on the 80th day or at harvest.

Table 18. Effect of phosphorus nutrition, liming and rhizobial inoculation on the total uptake of nitrogen by plants.

TREATMENTS	Uptake of nitrogen by plants (Kg/ha)			
	20th day after sowing	50th day after sowing	80th day after sowing	Harvest
Levels of phosphorus ($Kg\ P_2O_5/ha$)				
0	4.403	44.941	109.319	136.809
30	4.546	43.420	132.219	135.760
60	4.286	41.930	158.454	124.271
90	5.123	54.415	181.127	157.801
F test	NS	NS	Sig	NS
SEm ±	0.383	4.919	15.482	18.553
CD at 5%	-	-	44.709	-
Levels of lime (Kg/ha)				
0	4.533	44.828	146.832	145.593
250	4.647	47.525	143.727	131.727
F Test	NS	NS	NS	NS
SEm ±	0.270	3.478	10.948	13.119
CD at 5%	-	-	-	-
Rhizobial inoculation				
Uninoculated	4.525	45.512	149.875	130.998
Inoculated	4.654	46.841	140.684	146.322
F Test	NS	NS	NS	NS
SEm ±	0.270	3.478	10.948	13.119
CD at 5%	-	-	-	-

Significant interaction effect was observed between phosphorus and liming on the 80[th] day after sowing. Phosphorus at 90 kg P_2O_5/ha was significantly superior to 0, 30 and 60 kg P_2O_5/ha without lime. The same level was also superior to all levels of phosphorus at 250 kg lime/ha except for the treatment combination 60 kg P_2O_5 + 250 kg lime/ha. Control plot was also found inferior to 60 kg P_2O_5/ha with and without lime.

Nitrogen uptake by seeds increased from 80[th] day till harvest.

The results will be discussed subsequently while dealing total uptake of nitrogen by plants.

3.2.5 Total uptake of nitrogen by plants.

Data on the total nitrogen uptake by plants are presented in Table 18 Fig. 9 and the analysis of variance is given in Appendix XIV.

Uptake of nitrogen by plants were significantly affected by levels of phosphorus on the 80th day after sowing. At this stage, the highest level of 90 kg P_2O_5/ha was significantly superior to 0 and 30 kg P_2O_5/ha. The phosphorus level of 60 kg P_2O_5/ha which recorded a nitrogen uptake of 158 kg/ha was found to be significantly superior to the control with a nitrogen uptake of 109 kg/ha. At all other stages, phosphorus had no significant influence in the nitrogen uptake by plants but the general trend was in favour of an increase with increasing levels of applied phosphorus.

Levels of lime did not have any significant effect but the uptake of nitrogen was slightly improved by liming on the 20th and 50th days. On 80th day and at harvest reverse was the trend.

Although non-significant, rhizobial inoculation improved nitrogen uptake at all stages except on the 80th day after sowing. There was no significant interaction between phosphorus, liming and rhizobial inoculation.

Uptake of nitrogen by plants went on increasing with advancement of growth upto the 80th day but a slight fall was noticed at harvest.

From the results on total nitrogen uptake and nitrogen uptake by plant parts at different stages, it may be generally concluded that application of phosphorus did not have significant effect though there was significant increase in total uptake on the 80th day after sowing with increasing levels of phosphorus. If this trend of lack of increase in nitrogen uptake with increasing levels of phosphorus is accepted as a general trend, it would be contrary to the expected pattern. It is considered that phosphorus application in legumes would increase the accumulation of nitrogen through increased efficiency of nitrogen fixation and also through the direct involvement of phosphorus in crop nutrition. The critical level of phosphorus in soil for efficient nitrogen fixation is considered to be higher than that of the critical level for the direct nutrition of the legumes. Such an increased accu-mulation of nitrogen can either be reflected in terms of nitrogen content of tissue or through higher uptake. In the present study, there was no consistent increase in either nitrogen content or nitrogen uptake by plant parts. As concluded earlier, the results indicate adequacy of available phosphorus in soil.

A similar favourable response was also expected from application of lime and also by culture inoculation.

The reasons for lack of significant effect of these treatments have been discussed earlier.

The variation in nitrogen uptake at different stages of growth of the plant showed major difference between plant parts. For example in the case of stem and petiole, there was a conspicuous increase in the uptake of nitrogen upto the 50^{th} day after which there was a marginal decrease upto the 80^{th} day. There was a conspicuous decrease from 80^{th} day till harvest and the mean difference in uptake from the peak recorded on the 50^{th} day till harvest was 7.58 kg/ha. In the case of leaves there was a marked increase in uptake upto the 80^{th} day after sowing. The mean nitrogen uptake of leaves on the 80^{th} day comes to 29.97 kg/ha. In the case of shell, there was a decrease in uptake from the 80^{th} day after sowing till harvest, this decrease being to the extent of 8.03 kg. In the case of seeds, there was a marked increase in nitrogen uptake from 80^{th} day after sowing till harvest. The mean uptake by seeds at harvest comes to 117.78 kg. The decrease in uptake by stem and petiole and shell is presumably because of translocation of nitrogen to the developing grains. The total quantity of nitrogen thus translocated from stem + petiole and shell works out to 15.6 kg. There might have been a similar translocation of nitrogen from the leaves also but it is difficult to apportion the total of 29.97 kg accumulated in the leaves on the 80th day because there was complete defoliation after this stage and a certain quantity of nitrogen might have been lost through this. But even assuming that nearly all the nitrogen on the leaves was translocated to the grains prior to defoliation, the total quantity of nitrogen translocated from the plant parts to the grain works out to only about 45.57 kg. This comes to 39 per cent nitrogen in seeds. The remaining 61 per cent of the nitrogen in seeds must have come from absorption of the nutrient after the development of the seeds and its direct accumulation.

The results thus indicate the relative importance of maintaining conditions suitable for nitrogen fixation in this crop at the vegetative and reproductive phases of its growth. It may be reasonable to assume that in this crop, contribution of nitrogen accumulated in the vegetative parts towards grain filling is significant though the absorption in the reproductive phase is more important in terms of quantity.

A comparison of the proportion of the total nitrogen in different plant parts also show variation between stages. For example at the first stage of sampling, 20 days after sowing, nearly 76 per cent of the total nitrogen was accumulated in the leaves. At the next stage, 50 days after sowing also, the major part of nitrogen was concentrated in leaves. On the contrary, the major part of nitrogen in the plant on the 80th day was concentrated in the seed (55.6%) followed by leaves (20.8%), stem + petiole (11.8%) and then by shell (11.8%). Nearly the same trend continued at the harvest stage also, with the grains accounting for 44 per cent of the total nitrogen followed by stem + petiole and then by shell.

The discussion of nitrogen uptake pattern thus gives only general information on the crop. It was originally expected that pattern of nitrogen uptake by soybean would be different at varying levels of phosphorus and liming and because of culture inoculation. In the present investigation, because no significant effect of these treatments was noted, it is difficult to evaluate the difference in uptake pattern at varying

Table 19. Effect of phosphorus nutrition, liming and rhizobial inoculation on the phosphorus content of stem and petiole

TREATMENTS	Phosphorus content of stem and petiole(%)			
	20th day after sowing	50th day after sowing	80th day after sowing	Harvest
Levels of phosphorus ($Kg\ P_2O_5/ha$)				
0	0.100	0.219	0.115	0.044
30	0.122	0.245	0.137	0.043
60	0.103	0.225	0.110	0.039
90	0.088	0.224	0.120	0.028
F' test	NS	NS	NS	NS
SEm ±	0.018	0.013	0.016	0.008
CD at 5%	-	-	-	-
Levels of lime (Kg/ha)				
0	0.109	0.234	0.121	0.041
250	0.092	0.222	0.120	0.036
F' test	NS	NS	NS	NS
SEm ±	0.013	0.009	0.011	0.005
CD at 5%	-	-	-	-
Rhizobial inoculation				
Uninoculated	0.099	0.227	0.127	0.040
Inoculated	0.102	0.229	0.113	0.037
F' test	NS	NS	NS	NS
SEm ±	0.013	0.009	0.011	0.005
CD at 5%	-	-	-	-

Table 19 a. **Combined effect of phosphorus and liming on the phosphorus content (%) of stem and petiole on the 80th day after sowing**

Levels of phosphorus ($Kg\ P_2O_5/ha$)	Levels of lime (Kg/ha) 0	250	Mean
0	0.096	0.133	0.115
30	0.176	0.096	0.137
60	0.113	0.106	0.110
90	0.096	0.143	0.120
Mean	0.121	0.120	0.121

SEm ± 0.022

CD at 5% 0.065

levels of the above treatments.

3.3 Phosphorus content in different components.

3.3.1 Phosphorus content of stem and petiole.

Data on the phosphorus content of stem and petiole are presented in Table 19 and Fig.10 and the analysis of variance is given in Appendix XV.

Levels of phosphorus did not affect the phosphorus content of stem and petiole significantly at any of the stages namely 20th, 50th and 80th days and at harvest.

Levels of liming and rhizobial inoculation also could not exert any significant effect on the phosphorus content.

Significant interaction effect was noted between phosphorus and liming on the 80th day after sowing. Phosphorus level of 30 kg P_2O_5/ha without lime was found to be significantly superior to 0 and 90 kg P_2O_5/ha at the same level of lime. The above mentioned combination, 30 kg P_2O_5/ha without lime was found to be superior to same level of phosphorus applied with 250 kg lime/ha and also 60 kg P_2O_5 + 250 kg lime/ha, with respect to phosphorus content of stem and petiole.

Table 20. Effect of phosphorus nutrition, liming and rhizobial inoculation on the phosphorus content of leaves

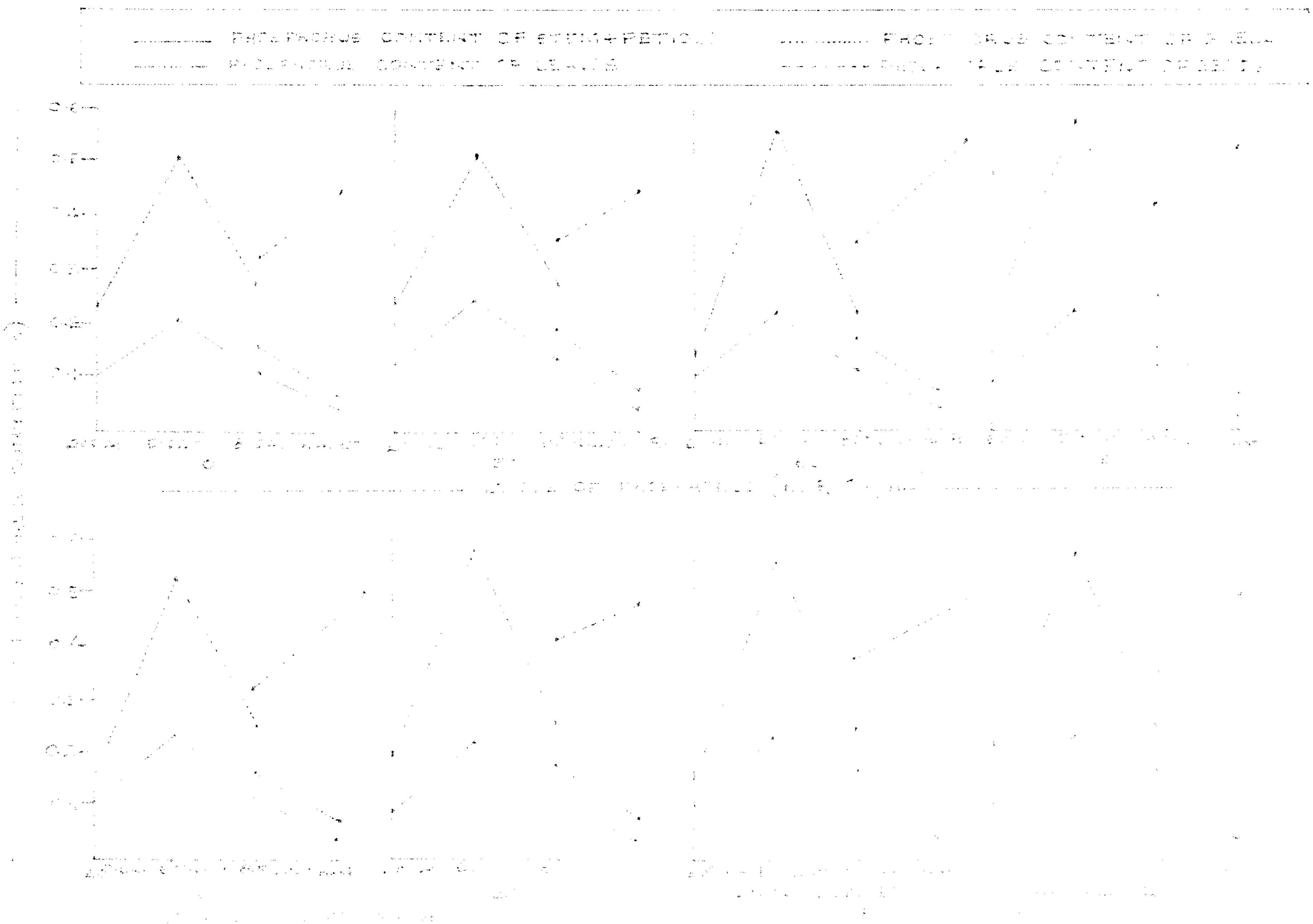
TREATMENTS		Phosphorus content of leaves(%)		
		20th day after sowing	50th day after sowing	80th day after sowing
Levels of phosphorus (Kg P_2O_5/ha)				
	0	0.229	0.508	0.267
	30	0.138	0.580	0.261
	60	0.142	0.560	0.221
	90	0.202	0.579	0.251
F' test		NS	NS	NS
SEm ±		0.033	0.030	0.016
CD at 5%		-	-	-
Levels of lime (Kg/ha)				
	0	0.164	0.531	0.249
	250	0.192	0.582	0.251
F' test		NS	NS	NS
SEm ±		0.023	0.021	0.011
CD at 5%		-	-	-
Rhizobial inoculation				
Uninoculated		0.153	0.557	0.246
Inoculated		0.203	0.557	0.254
F' test		NS	NS	NS
SEm ±		0.023	0.021	0.011
CD at 5%		-	-	-

Table 20 a. Combined effect of phosphorus and liming on the phosphorus content (%) of leaves on the 80th day after sowing

Levels of phosphorus ($Kg\ P_2O_5/ha$)	Levels of lime (Kg/ha)		Mean
	0	250	
0	0.222	0.312	0.267
30	0.268	0.254	0.261
60	0.266	0.175	0.221
90	0.238	0.264	0.251
Mean	0.249	0.251	0.250

SEm ± 0.022
CD at 5% 0.068

FIG-10 PHOSPHORUS CONTENT OF STEM+PETIOLE, LEAVES, SHELLS AND SEED AS AFFECTED BY DIFFERENT LEVELS OF PHOSPHORUS, LIMING AND RHIZOBIAL INOCULATION.



Percentage of phosphorus in stem + petiole was found to increase on the 50th day compared to the 20th day. But in the stages thereafter there was decrease in phosphorus content.

The results will be discussed later while dealing phosphorus content of seeds.

3.3.2 Phosphorus content of leaves.

Data on the phosphorus content in leaves at different stages are presented in Table 20 and Fig.10 and the analysis of variance is given in Appendix XVI.

Levels of phosphorus could not influence the phosphorus content of leaves significantly. All levels of the nutrient were on par at all the three stages namely 20th, 50th and 80th day after sowing.

Levels of liming also did not have significant effect on the phosphorus content. But, limed plots were found slightly superior to the control. Same trend of advantage was noticed with inoculated treatment over that of uninoculated one, although the effect was not significant.

Interaction between phosphorus and liming was significant on the 80th day. Treatment combination, 250 kg lime/ha without phosphorus was significantly superior to the control, 60 kg P_2O_5 + 250 kg lime/ha and 90 kg P_2O_5/ha without lime. Similarly, 60 kg P_2O_5/ha without lime was superior to same level of phosphorus applied with lime, 30 kg P_2O_5/ha with and without lime and 90 kg P_2O_5 + 250 kg lime/ha.

Percentage of phosphorus in leaves increased on the 50th day compared to the 20th day but decreased on 80th day.

Data on the phosphorus content of leaves will also be discussed later.

3.3.3 Phosphorus content of shell.

Data on the phosphorus content of shell are presented in Table 21 and Fig. 10 and analysis of variance is given in Appendix XV.

There was no significant difference between the levels of phosphorus with respect to phosphorus content in shell. Liming also could not exert any significant influence but had slight advantage over the control

Table 21. Effect of phosphorus nutrition, liming and rhizobial inoculation onthe phosphorus content of shell and seed

TREATMENTS	Phosphorus content (%) Shell		Seed	
	80th day after sowing	Harvest	80th day after sowing	Harvest
Levels of phosphorus ($Kg\ P_2O_5/ha$)				
0	0.160	0.068	0.323	0.444
30	0.192	0.083	0.354	0.445
60	0.171	0.082	0.351	0.542
90	0.156	0.071	0.433	0.527
F' test	NS	NS	NS	NS
SEm ±	0.016	0.009	0.040	0.042
CD at 5%	-	-	-	-
Levels of lime (Kg/ha)				
0	0.165	0.073	0.320	0.499
250	0.174	0.079	0.411	0.475
F' test	NS	NS	Sig.	NS
SEm ±	0.011	0.006	0.029	0.030
CD at 5%	-	-	0.084	-
Rhizobial inoculation				
Uninoculated	0.169	0.083	0.377	0.486
Inoculated	0.170	0.070	0.353	0.488
F' test	NS	NS	NS	NS
SEm ±	0.011	0.006	0.084	0.030
CD at 5%	-	-	-	-

Table 21 a. Combined effect of phosphorus and liming on the phosphorus content (%) of shell on the 80th day after sowing

Levels of phosphorus ($Kg\ P_2O_5/ha$)	Levels of lime (Kg/ha)		Mean
	0	250	
0	0.136	0.184	0.160
30	0.225	0.158	0.192
60	0.170	0.171	0.171
90	0.129	0.184	0.156
Mean	0.165	0.174	0.170

SEm ± 0.032

CD at 5% 0.065

with regard to phosphorus content. Inoculated set was also at par with the uninoculated series.

Significant interaction effect was noticed between phosphorus and liming on the 80th day after sowing. Unlimed plots at 30 kg P_2O_5/ha were found to be superior to 90 kg P_2O_5/ha, but this treatment was on par with 60 kg P_2O_5/ha. Similarly, 30 kg P_2O_5/ha without lime was significantly superior to 30 kg P_2O_5 + 250 kg lime/ha.

At harvest, percentage of phosphorus in shell was less compared to that on the 80th day.

The discussion on the phosphorus content of shell will be done later.

3.3.4 Phosphorus content of seeds.

Data on the phosphorus content of seeds are presented in Table 21 and Fig. 10 and the analysis of variance is given in Appendix XVI.

Levels of phosphorus could not affect the phosphorus content in seeds significantly either on the 80th day or at harvest. However, 90 kg P_2O_5/ha was found to be slightly better than other levels on the 80[th] day. At harvest, the upper two levels of phosphorus were better than the control and 30 kg P_2O_5/ha.

Higher dose of lime at 250 kg/ha was significantly superior to the control on the 80[th] day with respect to seed phosphorus content but both levels were at par at harvest stage.

Rhizobial inoculation could not exert any influence on the phosphorus content of seed at any of the stages. There was no significant interaction effect between phosphorus, liming and rhizobial inoculation.

From the data on phosphorus content of plant parts, it may be generally concluded that there was no significant difference between levels of phosphorus on the content of this nutrient in the plant parts. The interaction between phosphorus and liming also remained non-significant in most of the instances, though in some case there was significant interaction between them. Even where the interaction effect was significant, the results were not consistent. While discussing the results on other characters, it was concluded earlier that the effect of phosphorus on growth, yield and nitrogen uptake of soybean was not significant because the phosphorus supplying power of the soil was adequate enough both in terms of direct crop nutrition and also for efficient nitrogen fixation. The data on the phosphorus content of plant parts will further substantiate this view because even by applying phosphorus at the rate of 90 kg P_2O_5/ha, there was no substantial increase in the phosphorus content of plant parts at any of the stages. The review on the effect of applied phosphorus on the phosphorus content of soybean tissue generally indicates an increase in its content consequent to increase in its soil supplies (Pereira et al., 1974a; Kapoor and Gupta, 1977; Lutz and Jones,1975a) showing thereby that the deficiency of this nutrient in the soil is very well reflected in the content in plant parts. The fact that there was a consistent lack of significance because of phosphorus application substantiate the point that the phosphorus supply in soil originally might have been at the super-optiomal level.

Application of lime is known to increase the availability of phosphorus in acid soils. Results reported by Chatterjee et al., (1972a) also indicate such an increase in phosphorus content of soybean plant consequent to liming. It was therefore expected that application of lime will increase the phosphorus content of plant parts also. In the present study there was no such effect noticed persumably because even without added lime, the phosphorus requirement of the crop was adequately met.

Seed inoculation with the culture did not affect the phosphorus content of tissue. Such a result agrees with the earlier observations on the effect of inoculation on the other characters which have been discussed earlier.

Comparing between the stages, it is seen that phosphorus content of plant parts increased substantially from the 20th day to 50th day after sowing. There was a substantial decrease in the content of this nutrient with further advance in crop growth in the case of stem + petiole, between the 80th day after sowing and harvest. In the case of seeds, on the contrary, there was increase in the content of phosphorus from 80th day till harvest. The decrease in the phosphorus content of all the parts excepting grain after the 50th day indicates translocation of this nutrient to the developing

Table 22. Effect of phosphorus nutrition, liming and rhizobial inoculation on the uptake of phosphorus by stem and petiole

TREATMENTS	Uptake of phosphorus by stem and petiole (Kg/ha)			
	20th day after sowing	50th day after sowing	80th day after sowing	Harvest
Levels of phosphorus ($Kg\ P_2O_5/ha$)				
0	0.061	2.999	2.527	0.805
30	0.085	3.792	2.923	0.802
60	0.070	3.091	3.080	0.830
90	0.065	4.164	3.805	0.832
F' test	NS	Sig.	NS	NS
SEm ±	0.014	0.316	0.394	0.173
CD at 5%	-	0.914	-	-
Levels of lime (Kg/ha)				
0	0.077	3.392	3.022	0.823
250	0.064	3.630	3.145	0.712
F' test	NS	NS	NS	NS
SEm ±	0.010	0.224	0.277	0.122
CD at 5%	-	-	-	-
Rhizobial inoculation				
Uninoculated	0.069	3.376	3.200	0.785
Inoculated	0.072	3.647	2.877	0.750
F' test	NS	NS	NS	NS
SEm ±	0.010	0.224	0.277	0.122
CD at 5%	-	-	-	-

Table 22 a. Combined effect of phosphorus and liming on the uptake of phosphorus by stem and petiole (Kg/ha) on the 80th day after sowing

Level of phosphorus ($Kg\ P_2O_5$/ha)	Levels of lime (Kg/ha) 0	250	Mean
0	2.303	2.751	2.527
30	3.668	2.178	2.923
60	3.256	2.903	3.080
90	2.861	4.750	3.805
Mean	3.022	3.145	3.084

SEm ± 0.556

CD at 5% 1.605

grains. This point will become clearer while comparing the phosphorus uptake of plant parts at different stages.

3.4 Uptake of phosphorus by different components.

3.4.1 Uptake of phosphorus by stem and petiole.

Data on the uptake of phosphorus at various stages are presented in Table 22 and Fig. 11 and the analysis of variance is given in Appendix XVII.

Application of varying levels of phosphorus did not result in an increase in the uptake of phosphorus throughout the growth period of soybean except on the 50th day after sowing. At this stage, the highest level of 90 kg P_2O_5/ha gave the maximum and control plot recorded the minimum uptake value of phosphorus by stem + petiole. Phosphorus at 90 kg P_2O_5/ha was significantly superior to control and 60 kg P_2O_5/ha.

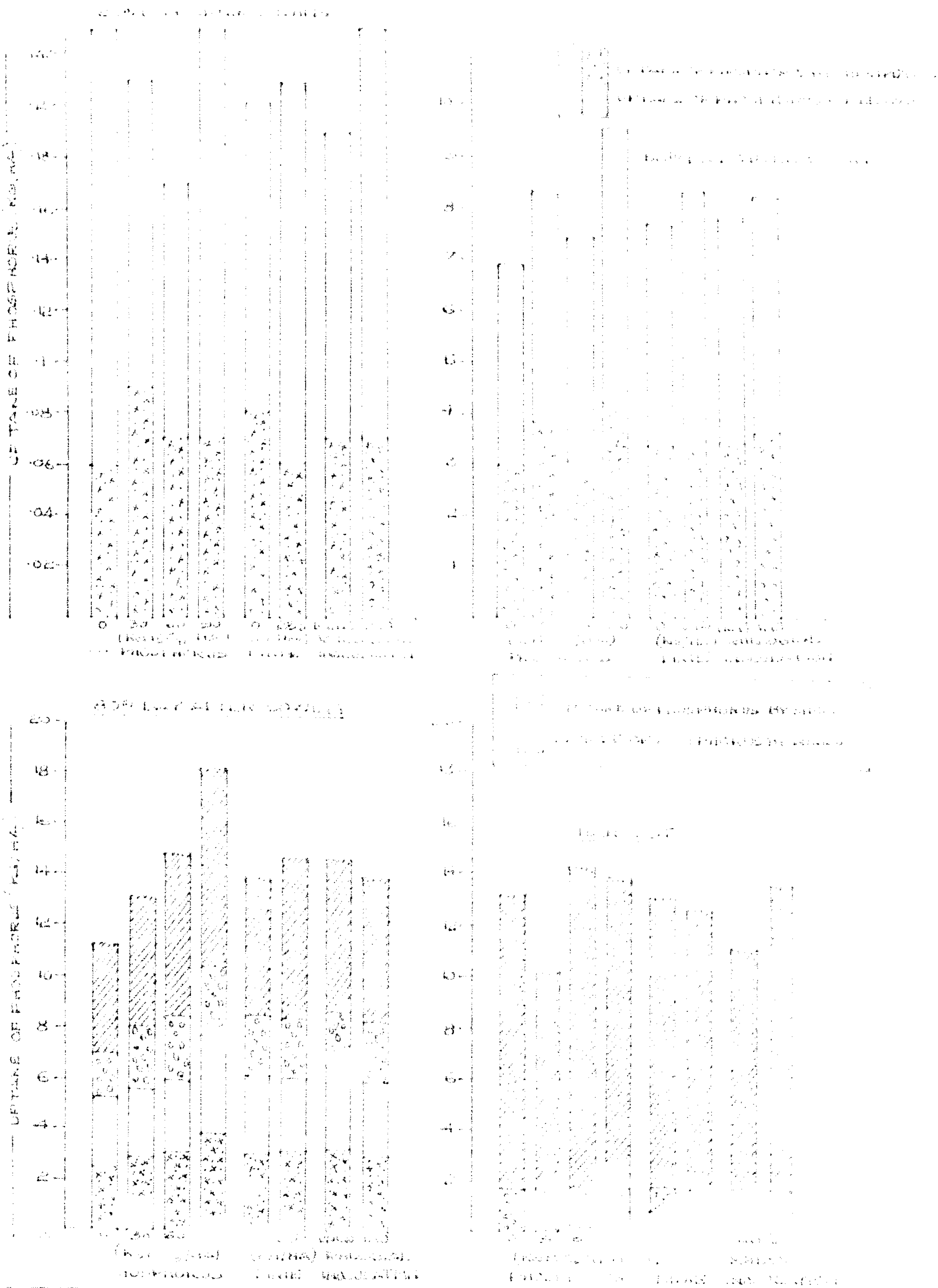
Neither liming nor inoculation could exert any significant influence in the uptake of phosphorus at any of the stages.

Significant interaction between phosphorus and liming was observed on the 80th day after sowing. When

Table 23. Effect of phosphorus nutrition, liming and rhizobial inoculation on the uptake of phosphorus by leaves

TREATMENTS	Uptake of phosphorus by leaves (Kg/ha)		
	20th day after sowing	50th day after sowing	80th day after sowing
Levels of phosphorus ($Kg\ P_2O_5/ha$)			
0	0.170	3.862	2.678
30	0.119	4.452	2.743
60	0.101	4.337	2.801
90	0.162	5.306	3.875
F' test	NS	NS	NS
SEm ±	0.024	0.392	0.365
CD at 5%	-	-	-
Levels of lime (Kg/ha)			
0	0.122	4.258	3.115
250	0.154	4.720	2.934
F' test	NS	NS	NS
SEm ±	0.017	0.277	0.257
CD at 5%	-	-	-
Rhizobial inoculation			
Uninoculated	0.117	4.426	3.064
Inoculated	0.159	4.553	2.985
F' test	NS	NS	NS
SEm ±	0.017	0.277	0.257
CD at 5%	-	-	-

FIG. 11



90 kg P_2O_5/ha was applied in combination with 250 kg lime/ha, the uptake was significantly higher than control and treatment combinations of 250 kg lime/ha without phosphorus, 30 kg P_2O_5 + 250 kg lime/ha, 60 kg P_2O_5 + 250 kg lime/ha and 90 kg P_2O_5/ha without lime.

Phosphorus uptake by stem + petiole increased till the 50th day stage which remained almost constant till the 80th day but decreased thereafter.

The results will be discussed while dealing with the total phosphorus uptake by plants.

3.4.2 Uptake of phosphorus by leaves.

Data on the uptake of phosphorus by leaves are presented in Table 23 and Fig.11 and the analysis of variance in Appendix XVIII.

Levels of phosphorus did not affect the phosphorus uptake significantly at any of the stages except for slight advantage noted at the highest dose of phosphorus at 90 kg P_2O_5/ha on the 50th and 80th day after sowing.

Liming and rhizobial inoculation also could not affect the uptake value significantly. Interaction effects were not significant.

Phosphorus uptake of leave increased upto the 50^{th} day and decreased thereafter.

Results will be discussed while dealing total uptake of phosphorus by plants.

3.4.3 Uptake of phosphorus by shell.

Data on the uptake of phosphorus by shell are presented in Table 24 and Fig.11 and the analysis of variance is given in Appendix XVII.

Application of phosphorus did not exert any significant change in the uptake of phosphorus by shell. However, a gradual increase was observed with increasing levels of phosphorus on the 80^{th} day after sowing. Similar tread was observed at harvest stage only upto 60 kg P_2O_5/ha.

Liming or rhizobial inoculation did not have any significant effect on the phosphorus uptake by shell. Interaction effects between phosphorus, liming and inoculation were not significant.

Phosphorus uptake decreased at harvest stage compared to that on the 80^{th} day after sowing.

Table 24. Effect of phosphorus nutrition, liming and rhizobial inoculation on the uptake of phosphorus by shell and seeds

TREATMENTS	Uptake of phosphorus (Kg/ha)			
	Shell		Seeds	
	80th day after sowing	Harvest	80th day after sowing	Harvest
Levels of phosphorus ($Kg\ P_2O_5/ha$)				
0	1.791	0.882	4.153	11.612
30	2.402	0.926	4.953	8.618
60	2.512	1.015	6.395	11.535
90	2.570	0.870	7.841	12.231
F' test	NS	NS	Sig.	NS
SEm ±	0.324	0.182	0.903	1.823
CD at 5%	-	-	2.601	-
Levels of lime (Kg/ha)				
0	2.341	0.897	5.408	11.364
250	2.297	0.949	6.263	10.989
F' test	NS	NS	NS	NS
SEm ±	0.228	0.126	0.639	1.289
CD at 5%	-	-	-	-
Rhizobial inoculation				
Uninoculated	2.325	0.912	5.937	10.444
Inoculated	2.313	0.935	5.735	11.909
F' test	NS	NS	NS	NS
SEm ±	0.228	0.126	0.639	1.289
CD at 5%	-	-	-	-

Table 24 a. Combined effect of phosphorus and liming on the uptake of phosphorus by seeds (Kg/ha) on the 80th day after sowing

Levels of phosphorus ($Kg\ P_2O_5/ha$)	Levels of lime (Kg/ha)		Mean
	0	250	
0	4.621	3.685	4.153
30	4.570	5.336	4.953
60	3.703	9.088	6.395
90	8.740	6.943	7.841
Mean	5.408	6.263	5.836

SEm ± 1.274

CD at 5% 3.679

Discussion on this aspect will be covered under total uptake of phosphorus by plants.

3.4.4 Uptake of phosphorus by seeds.

Data on the uptake of phosphorus by seeds are presented in Table 24 and Fig.11 and the analysis of variance is given in Appendix XVIII.

The data reveal that higher levels of applied phosphorus enhanced uptake of phosphorus by seeds significantly on the 80^{th} day after sowing but all the treatments were at par at harvest stage. On the 80^{th} day, application of phosphorus at 90 kg P_2O_5/ha resulted in maximum uptake of phosphorus by seeds and this treatment was significantly superior to application of phosphorus upto 30 kg P_2O_5/ha.

There was no significant difference in the character either due to lime application or due to rhizobial inoculation.

Interaction effect between phosphorus and liming was observed to be significant on the 80^{th} day. Highest dose of phosphorus at 90 kg P_2O_5/ha gave significantly higher uptake of phosphorus by seeds compared to control, 30 kg and 60 kg P_2O_5/ha when

TABLE 25. **Effect of phosphorus nutrition, liming and rhizobial inoculation on the total uptake of phosphorus by plants**

TREATMENTS		Total uptake of phosphurs (Kg/ha)			
		20th day after sowing	50th day after sowing	80th day after sowing	Harvest
Levels of phosphorus ($Kg\ P_2O_5/ha$)					
	0	0.211	9.194	11.169	13.272
	30	0.207	8.251	12.625	10.354
	60	0.172	7.410	14.640	13.430
	90	0.235	9.487	18.194	14.514
F' test		NS	NS	Sig.	NS
SEm ±		0.032	0.892	1.688	1.969
CD at 5%		-	-	4.876	-
Levels of lime (Kg/ha)					
	0	0.193	8.804	13.906	13.127
	250	0.219	8.366	14.409	12.658
F' test		NS	NS	NS	NS
SEm ±		0.022	0.631	1.194	1.392
CD at 5%		-	-	-	-
Rhizobial inoculation					
Uninoculated		0.181	8.964	14.552	12.169
Inoculated		0.231	8.207	13.762	13.616
F' test		NS	NS	NS	NS
SEm ±		0.022	0.631	1.194	1.392
CD at 5%		-	-	-	-

Table 25 a. Combined effect of phosphorus and liming on the total uptake of phosphorus by plants (Kg/ha) on the 50th day after sowing

Levels of phosphorus ($Kg\ P_2O_5/ha$)	Levels of lime(Kg/ha)		Mean
	0	250	
0	11.770	6.770	9.194
30	7.866	8.636	8.251
60	7.044	7.776	7.410
90	8.537	10.436	9.487
Mean	8.804	8.366	8.585

SEm ± 1.261

CD at 5% 3.643

Table 25 b. Combined effect of phosphorus and rhizobial inoculation on the total uptake of phosphorus by plants (Kg/ha) on the 50th day after sowing

Levels of phosphorus ($Kg\ P_2O_5/ha$)	Levels of rhizobial inoculation		Mean
	Uninoculated	Inoculated	
0	11.772	6.617	9.194
30	7.442	9.060	6.580
60	8.241	6.580	7.410
90	8.401	10.571	9.487
Mean	8.964	8.207	8.586

SEm ± 1.261

CD at 5% 3.643

lime was not applied. On the other hand when lime was applied, 60 kg P_2O_5/ha recorded the maximum uptake of phosphorus which was significantly higher than the control and 30 kg P_2O_5/ha.

There was increase in uptake of phosphorus by seeds at harvest stage compared to that on the 80th day after sowing.

3.4.5 Total uptake of phosphorus by plants.

Data on the total uptake of phosphorus by plants are presented in Table 25 Fig.11 and the analysis of variance is given in Appendix XIX.

Levels of phosphorus had significant effect on the uptake of phosphorus by plants on the 80th day after sowing. Highest level of applied phosphorus recorded the highest uptake value at this stage which was significantly superior to the control and phosphorus at 30 kg P_2O_5/ha. At all other stages, difference between levels of phosphorus were not significant. Liming and rhizobial inoculation failed to exert significant effect on the phosphorus uptake.

Interaction between phosphorus and liming was significant on the 50th day after sowing. Treatment receiving no phosphorus or lime was found to be significantly superior to treatments where lime only was applied and to plots supplied with 30 kg and 60 kg P_2O_5/ha without lime. Control plot was also superior to treatment combination 60 kg P_2O_5 + 250 kg lime but was at par with other treatments. Similarly phosphorus at the rate of 90 kg P_2O_5/ha in combination with lime was significantly superior to the treatment with no phosphorus at the same level of lime.

Interaction between phosphorus and rhizobial inoculation was significant on the 50th day after sowing. Treatment receiving neither phosphorus nor inoculation was significantly superior to treatment receiving phosphorus alone at 30 kg P_2O_5/ha. Control plot was also superior to treatment combinations 0 and 60 kg P_2O_5 with rhizobial inoculation. Similarly, 90 kg P_2O_5/ha in combination with rhizobial inoculation was significantly superior to treatment combinations, 0 and 60 kg P_2O_5 with rhizobial inoculation. Interaction between phosphorus, liming and rhizobial inoculation was also found to be significant.

An evaluation of the overall effect of various treatments on the uptake of phosphorus will reveal that there was no consistent significant effect of either phosphorus application, liming or culture inoculation. This is to be normally expected because there was no such significant effect of the different treatments either on the dry weight of plant or phosphorus content of the plant parts. The reasons for this have been already discussed and the major conclusion of such results have been drawn while discussing the phosphorus content of plant parts. The following discussion is meant only to elaborate on the uptake pattern of phosphorus in different plant components. As it is in the case of nitrogen, there was a steady increase in the phosphorus uptake of stem + petiole upto the 80^{th} day after which there was a substantial decrease. In the case of leaves it increased substantially upto the 50^{th} day, after which there was marked decline upto the 80^{th} day after sowing. There was a similar drop in the phosphorus uptake by shell from the 80th day till harvest. In contrast, the uptake of phosphorus by seeds nearly doubled from 80^{th} day till harvest. A comparison of the total phosphorus uptake at various stages will reveal that there was a steady rate of increase in the uptake of phosphorus upto the 80th day after sowing. It remained constant thereafter.

Comparing the phosphorus uptake of stem + petiole on the 50th day after sowing and harvest, it may be noted that it dropped from an average of 3.5 kg/ha on the 50th day to about 0.8 kg at harvest. A similar quantitative estimate of the decrease in uptake of phosphorus by leaves between 50th day and harvest is not possible as the content of phosphorus in the leaves at harvest stage could not be estimated. In the case of shell, phosphorus uptake decreased from 2.3 kg to about 0.9 kg/ha between 80th day and harvest. The gain in the uptake of phosphorus from the 80th day to harvest in seeds was from an average of 5.8 to 11.2 kg/ha. As it was in the case of nitrogen, an attempt is made to assess the quantity of this nutrient translocated from different parts to the grain. In the case of stem + petiole, the quantity of phosphorus lost from the tissue works out to 2.74 kg between the stages, 50th day after sowing and harvest. Inthe case of shell, the quantity similarly lost works out to 1.4 kg. Assuming that all the phosphorus contained in the leaves on the 80th day was completely translocated to the grain, the contribution by leaves works out to 3.02 kg. The total quantity of phosphorus thus translocated from different plant parts works out to 7.16 kg. The total quantity of phosphorus in the grain at harvest was 11.22 kg. The percentage of the nutrient in the seed acquired through translocation works out to 64%. This is in marked contrast to nitrogen in which case only 39% were estimated to be received by translocation.

As it was done in the case of nitrogen, an attempt is also made to assess the pattern of accumulation of phosphorus in different parts at various stages, and it was seen that on the 20^{th} day, the major portion of phosphorus (66.2%) was in the leaves which had decreased to 56.1 per cent on the 50^{th} day. On 80^{th} day after sowing, accumulation was maximum in seeds (41.0%) followed by stem + petiole (21.4%). Proportions of phosphorus in leaves and shell were 21.3 per cent and 16.3 per cent respectively at this stage. At harvest, phosphorus uptake by seeds considerably increased to the tune of 86.9 per cent of the total uptake which was followed by shell (7.1%) and stem + petiole (6.0%).

Table 26. Effect of phosphorus nutrition, liming and rhizobial inoculation on the calcium content of stem and petiole.

TREATMENTS		Calcium content of stem + petiole(%)			
		20th day after sowing	50th day after sowing	80th day after sowing	Harvest
Levels of phosphorus ($Kg\ P_2O_5/ha$)					
	0	1.277	0.867	0.673	0.615
	30	1.592	0.907	0.540	0.620
	60	1.413	0.911	0.811	0.629
	90	1.531	0.860	0.707	0.629
F' test		NS	NS	Sig.	NS
SEm ±		0.095	0.068	0.044	0.042
CD at 5%		-	-	0.127	-
Levels of lime (Kg/ha)					
	0	1.458	0.928	0.703	0.691
	250	1.448	0.845	0.662	0.556
F' test		NS	NS	NS	Sig.
SEm ±		0.067	0.048	0.031	0.030
CD at 5%		-	-	-	0.085
Rhizobial inoculation					
Uninoculated		1.517	0.921	0.676	0.645
Inoculated		1.390	0.851	0.689	0.601
F' test		NS	NS	NS	NS
SEm ±		0.067	0.048	0.031	0.030
CD at 5%		-	-	-	-

Table 26 a. **Combined effect of phosphorus and liming on the calcium content (%) of stem and petiole on the 80th day after sowing**

Levels of phosphorus (Kg P_2O_5/ha)	Levels of lime (Kg/ha) 0	250	Mean
0	0.584	0.761	0.673
30	0.557	0.522	0.540
60	0.894	0.727	0.811
90	0.775	0.639	0.707
Mean	0.703	0.662	0.683

SEm ± 0.063

CD at 5% 0.179

3.5 Calcium content in different components.

3.5.1 Calcium content of stem and petiole.

Data on the calcium content of stem and petiole are presented in Table 26 and Fig.12 and the analysis of variance is given in Appendix XX.

Levels of phosphorus applied did not produce any significant difference in the calcium content of stem + petiole at any of the stages except at the third stage of observation, 80th day after sowing. At this stage , phosphorus level at 60 kg P_2O_5/ha recorded the highest calcium content which was significantly superior to the control plot and 30 kg P_2O_5/ha level. Highest level of 90 kg P_2O_5/ha was found to be significantly superior only to 30 kg P_2O_5/ha level and was at par with other treatments.

Liming did not have any effect at any of the stages except for the significant negative effect noted at harvest. There was no effect of rhizobial inoculation. Inoculated set was on par with the uninoculated at all the stages of growth.

Table 27. Effect of phosphorus nutrition, liming and rhizobial inoculation on the calcium content of leaves

TREATMENTS	Calcium content of leaves (%)		
	20th day after sowing	50th day after sowing	80th day after sowing
Levels of phosphorus ($Kg\ P_2O_5/ha$)			
0	1.331	1.734	1.634
30	1.579	1.710	1.611
60	1.666	1.900	1.710
90	1.538	1.816	1.992
F' test	NS	NS	NS
SEm ±	0.110	0.100	0.115
CD at 5%	-	-	-
Levels of lime (Kg/ha)			
0	1.517	1.762	1.782
250	1.540	1.817	1.695
F' test	NS	NS	NS
SEm ±	0.078	0.071	0.081
CD at 5%	-	-	-
Rhizobial inoculation			
Uninoculated	1.482	1.838	1.772
Inoculated	1.574	1.741	1.706
F' test	NS	NS	NS
SEm ±	0.078	0.071	0.081
CD at 5%	-	-	-

Fig-12 CALCIUM CONTENT OF STEM+PETIOLE, LEAVES, SHELL AND SEEDS AS AFFECTED BY DIFFERENT LEVELS OF PHOSPHORUS, LIME AND RHIZOBIAL INOCULATION.

Interaction effect due to phosphorus and liming was noticed on the 80th day after sowing. Treatment with phosphorus at 60 kg P_2O_5/ha without lime recorded the highest calcium content which was significantly superior to 0 or 30 kg P_2O_5/ha without lime. The above mentioned treatment was also superior to 30 kg P_2O_5 + 250 kg lime/ha. Phosphorus at the rate of 90 kg P_2O_5 without lime was superior to phosphorus level of 0 and 30 kg P_2O_5/ha without lime in addition to treatment combinations of 30 kg P_2O_5 + 250 kg lime/ha. Lime at 250 kg/ha without phosphorus was significantly superior to the treatment of 30 kg P_2O_5/ha at same level of liming. Similarly, 60 kg P_2O_5 + 250 kg lime/ha was significantly superior to treatment combination 30 kg P_2O_5 + 250 kg lime/ha with respect to calcium content in stem + petiole.

The general trend showed a gradual decrease in the percentage of calcium in stem + petiole with advancement of crop growth.

The discussion on this aspect will be done later.

3.5.2 <u>Calcium content of leaves</u>.

Data on the calcium content of leaves are recorded in Table 27 and Fig. 12 and the analysis of variance is given in Appendix XXI.

Levels of phosphorus did not have any significant effect on the calcium content of leaves. Liming or rhizobial inoculation also could not influence the character significantly. There was no interaction effect between the treatments at any of the stages.

Percentage of calcium in leaves over the stages did not differ much and the content remained steady from 20th day till the 30th day though a slight increase in percentage was noticed from 20th to 50th day.

The result will be discussed later.

3.5.3 Calcium content of shell.

Data on the calcium content of shell are presented in Table 28 and Fig. 12 and the analysis of variance is given in Appendix XX.

Application of phosphorus did not exert any significant effect either on the 80th day after sowing or at harvest. However, the general trend indicates an increase in the calcium content with increased levels of phosphorus.

Table 28. Effect of phosphorus nutrition, liming and rhizobial inoculation on the calcium content of shell and seeds

TREATMENTS	Calcium content (%)			
	Shell		Seed	
	80th day after sowing	Harvest	80th day after sowing	Harvest
Levels of phosphorus ($Kg\ P_2 O_5$ /ha)				
0	0.955	1.091	0.567	0.384
30	0.928	0.935	0.416	0.415
60	0.986	1.162	0.457	0.391
90	1.006	1.043	0.463	0.346
F' test	NS	NS	NS	NS
SEm ±	0.075	0.076	0.050	0.034
CD at 5%	-	-	-	-
Levels of lime (Kg/ha)				
0	0.994	1.021	0.486	0.389
250	0.943	1.094	0.465	0.379
F' test	NS	NS	NS	NS
SEm ±	0.053	0.054	0.035	0.024
CD at 5%	-	-	-	-
Rhizobial inoculation				
Uninoculated	0.980	1.023	0.484	0.362
Inoculated	0.957	1.092	0.467	0.406
F' test	NS	NS	NS	NS
SEm ±	0.053	0.054	0.035	0.024
CD at 5%	-	-	-	-

Liming and inoculation also failed to cause significant effect on the character at either of the stages. There was no interaction effect between the pair of factors.

The results will be discussed later while discussing the results on the calcium content of seeds.

3.5.4 Calcium content of seeds.

Data on the calcium content of seeds are presented in Table 28 and Fig.12 and the analysis of variance in Appendix XXI.

Phosphorus levels did not have any significant effect on the calcium content of seeds either on the 80th day or at harvest. Liming and rhizobial inoculation also did not have significant effect. No significant interaction effect was noticed at any stage.

Percentage calcium in seeds slightly fell at harvest stage compared to that on the 80th day after sowing.

Application of phosphorus, lime and culture inoculation in general did not have any effect on the calcium content of the tissues. However, the effect of phosphorus was significant in the case of calcium content of stem + petiole at one stage. Similarly, the interaction between phosphorus and liming was also significant at one stage and at all other stages the effects were non-significant. If the isolated instances of statistical significance noticed in these two cases are neglected considering them as exceptions, the general conclusion would be that the supply of calcium in the soil was adequate enough for the crop. Normally it is expected that application of phosphorus will decrease the availability of calcium because of formation of insoluble salts of phosphorus and calcium. The results reported by Kapoor and Gupta (1977) also showed such a decrease in the calcium content of soybean by application of phosphatic fertilizers. In the present study, there was no such consistant decrease in the calcium content of soybean tissues. This again supports the earlier conclusion that the calcium content in soil was sufficient enough for maintaining adequate supplies of calcium to the crop. The probable decrease in the availability of calcium because of application of phosphorus upto 90 kg P_2O_5/ha could not probably affect the calcium supply to the crop significantly. The same conclusions as above could be drawn by a comparison of calcium content of tissues with and without application of lime. Surprisingly, even application of lime at 250 kg/ha could not increase the calcium content of plant parts at any of the stages. This is however contrary to the results reported by (Kanki et al., 1974 and Chatterjee et al., 1972) who found an increase in calcium content when liming was done.

There appears to be no reason why culture inoculation should alter the calcium content of plants. However, Chatterjee et al.(1972) found an increase in calcium content of soybean seeds consequent to culture inoculation. In this experiment, there was no such consistent effect of culture inoculation on calcium content.

Comparing between the stages, there was a substantial decrease in the calcium content of stem + petiole with advancing age till harvest and a slight decrease in the calcium content of seeds. In the leaves the calcium content remained more or less

Table 29. Effect of phosphorus nutrition, liming and rhizobial inoculation on the uptake of calcium by stem and petiole

TREATMENTS	Uptake of calcium by stem and petiole (Kg/ha)			
	20th day after sowing	50th day after sowing	80th day after sowing	Harvest
Levels of phosphorus ($Kg\ P_2O_5/ha$)				
0	0.779	11.946	15.454	11.297
30	1.080	13.417	15.181	10.819
60	0.922	12.297	22.961	11.902
90	1.081	15.558	23.030	14.478
F' test	Sig.	NS	Sig.	NS
SEm ±	0.084	1.525	2.311	1.655
CD at 5%	0.238	-	6.673	-
Levels of lime (Kg/ha)				
0	0.927	13.227	19.390	13.415
250	1.004	13.382	18.923	10.833
F' test	NS	NS	NS	NS
SEm ±	0.055	1.078	1.634	1.170
CD at 5%	-	-	-	-
Rhizobial inoculation				
Uninoculated	0.963	13.197	18.779	11.936
Inoculated	0.968	13.412	19.534	12.312
F' test	NS	NS	NS	NS
SEm ±	0.055	1.078	1.634	1.170
CD at 5%	-	-	-	-

steady from 20th to 80th day after sowing whereas in the shell, there was slight increase. Calcium is generally considered to be an element that is immobile in the plant and if this is true in soybean also, the lower calcium content of stem + petiole with advancing age can only be justified by assuming that the rate of absorption of this element at later stages (as compared to increase in dry matter accumulation) was substantially lower than its rate of absorption in the early stages. The slight increase in the content of calcium in shell and decrease in seeds from 80th day to harvest should be taken to be again a result of difference in the rate of uptake of calcium and increase in dry matter accumulation.

3.6 Uptake of calcium by different components.

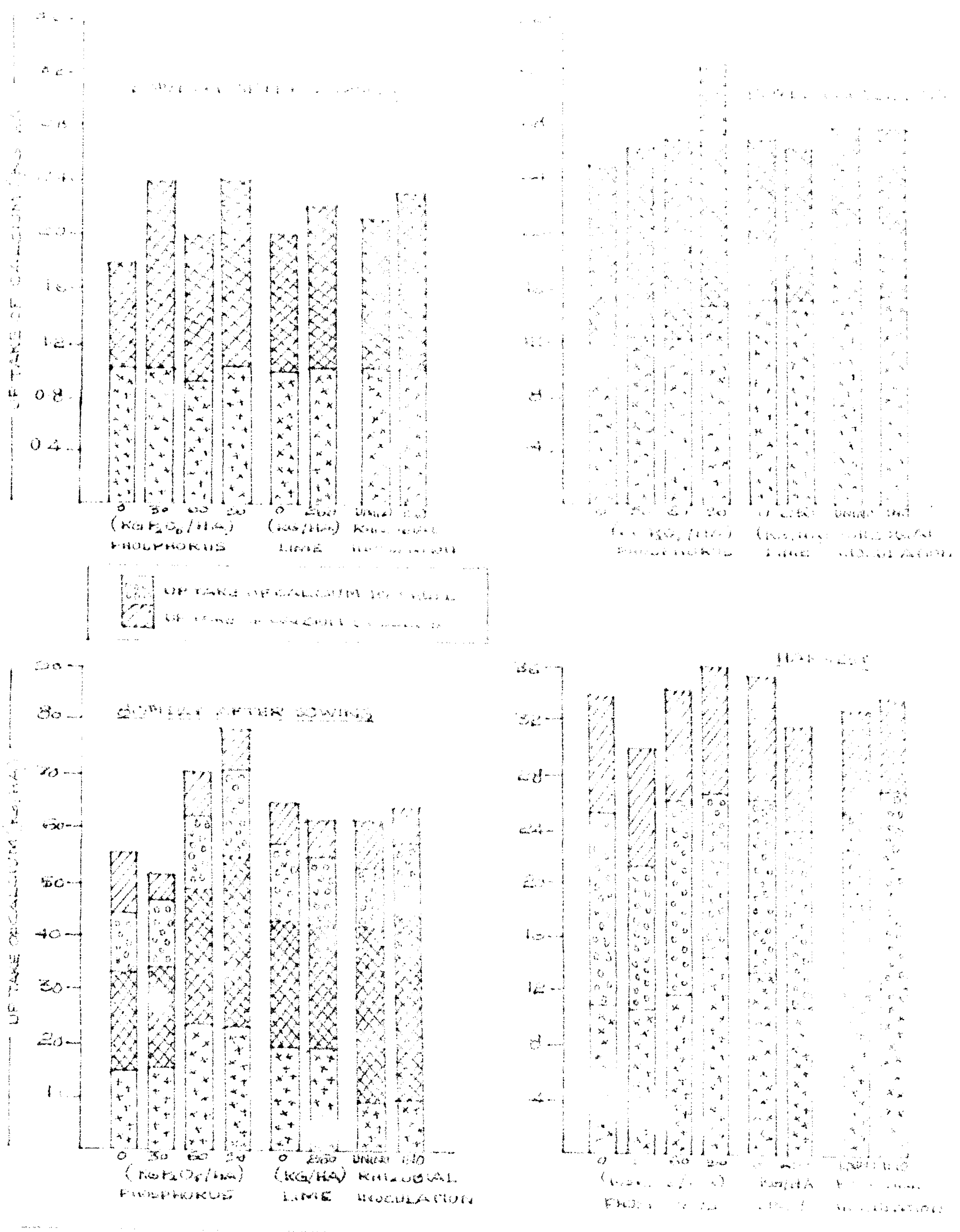
3.6.1 Uptake of calcium by stem and petiole.

Data on the uptake of calcium by stem and petiole are presented in Table 29 and Fig. 13 and the analysis of variance is given in Appendix XXII.

Effect of levels of phosphorus was found to be significant on the 20th and 80th day after sowing with

Table 30. Effect of phosphorus nutrition, liming and rhizobial inoculation on the uptake of calcium by leaves

TREATMENTS		Uptake of calcium by leaves (Kg/ha)		
		20th day after sowing	50th day after sowing	80th day after sowing
Levels of phosphorus (Kg P_2O_5/ha)				
	0	0.975	12.987	17.375
	30	1.338	13.150	18.755
	60	1.118	14.700	25.505
	90	1.270	17.065	32.166
F' test		NS	NS	Sig.
SEm ±		0.150	1.302	3.716
CD at 5%		-	-	10.729
Levels of lime (Kg/ha)				
	0	1.175	14.107	23.475
	250	1.210	14.844	23.425
F' test		NS	NS	NS
SEm ±		0.071	0.920	2.627
CD at 5%		-	-	-
Rhizobial inoculation				
Uninoculated		1.125	14.670	22.997
Inoculated		1.260	14.281	23.903
F' test		NS	NS	NS
SEm ±		0.071	0.920	2.627
CD at 5%		-	-	-


UPTAKE OF CALCIUM
PHOSPHORUS
LIME
RHIZOBIAL INOCULATION
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respect to calcium uptake by stem + petiole but was non-significant on the 50^{th} day and at harvest stage. On the 20^{th} day, 30 and 90 kg P_2O_5/ha were significantly superior to control. On the 80^{th} day, 60 and 90 kg P_2O_5/ha were significantly superior to the lower two levels, the control and 30 kg P_2O_5/ha.

Liming and rhizobial inoculation did not produce any significant effect on the calcium uptake by stem + petiole at any of the stages. There was no significant interaction effect between phosphorus, liming and inoculation.

Calcium uptake was found to increase from 20^{th} day to the 80^{th} day after sowing. There was conspicuous decrease in mean uptake of calcium from 80^{th} day till harvest.

The discussion on this aspect will be covered later.

3.6.2 Uptake of calcium by leaves.

Data on the uptake of calcium by leaves are presented in Table 30 and Fig.13 and the analysis of variance is given in Appendix XXIII.

Effect of levels of phosphorus applied was found to be significant on the 80th day after sowing with respect to the uptake of calcium by leaves. Highest level of phosphorus applied was significantly superior to the control and 30 kg P_2O_5/ha but was at par with 60 kg P_2O_5/ha. With increasing levels of phosphorus applied, the uptake by this plant component was also found to increase at all the stages. The effect due to varying levels of phosphorus was not significant on both 20th and 50th day.

Liming and rhizobial inoculation did not show any significant effect. There was no significant interaction effect due to the treatments.

Calcium uptake by leaves increased from 20th day till the last stage of observation, 80 days after sowing.

The discussion on this aspect will be done while dealing total calcium uptake by plants.

3.6.3 Uptake of calcium by shell.

Data on the uptake of calcium by shell are presented in Table 31 and Fig.13 and the analysis of

Table 31. Effect of phosphorus nutrition, liming and rhizobial inoculation on the uptake of calcium by shell and seed

TREATMENTS	Uptake of calcium (Kg/ha)			
	Shell		Seeds	
	80th day after sowing	Harvest	80th day after sowing	Harvest
Levels of phosphorus ($Kg\ P_2O_5/ha$)				
0	10.803	13.972	6.765	8.673
30	12.490	10.430	5.807	8.251
60	14.133	14.269	7.315	8.080
90	15.247	13.149	8.008	8.254
F' test	NS	NS	NS	NS
SEm ±	1.480	1.355	1.066	1.063
CD at 5%	-	-	-	-
Levels of lime (Kg/ha)				
0	14.167	12.815	7.152	8.970
250	12.170	13.095	6.795	7.659
F' test	NS	NS	NS	NS
SEm ±	1.046	0.959	0.754	0.752
CD at 5%	-	-	-	-
Rhizobial inoculation				
Uninoculated	12.723	11.692	6.985	7.425
Inoculated	13.613	14.218	6.962	9.205
F' test	NS	NS	NS	NS
SEm ±	1.046	0.959	0.754	0.752
CD at 5%	-	-	-	-

Table 31 a. Combined effect of phosphorus and liming on the uptake of calcium by shell (Kg/ha) at harvest

Levels of phosphorus ($Kg\ P_2O_5/ha$)	Levels of lime(Kg/ha) 0	250	Mean
0	16.911	11.911	13.972
30	11.928	8.931	10.430
60	11.566	16.971	14.269
90	10.853	15.445	13.149
Mean	12.815	13.059	12.937

SEm ± 1.917

CD at 5% 5.536

variances is given in Appendix XXII.

Calcium uptake by shell could not be significantly influenced by levels of phosphorus applied, liming or rhizobial inoculation, either on the 80th day or at harvest stage.

Significant interaction effect due to phosphorus and liming on the uptake of calcium by shell was noted at harvest. At 250 kg lime/ha, 60 and 90 kg P_2O_5/ha were significantly superior to 30 kg P_2O_5/ha but these were at par with control.

Results will be discussed while dealing total uptake of calcium by plants.

3.6.4 Uptake of calcium by seeds.

Data on the uptake of calcium by seeds are presented in Table 31 and Fig. 13 and the analysis of variance is given in Appendix XXIII.

There was no significant difference in the uptake of calcium by seeds due to different levels of phosphorus, liming or rhizobial inoculation. Interaction effects were also not significant.

Table 32. Effect of phosphorus nutrition, liming and rhizobial inoculation on the total uptake of calcium by plants

TREATMENTS	Total uptake of calcium by plants (Kg/ha)			
	20th day after sowing	50th day after sowing	80th day after sowing	Harvest
Levels of phosphorus ($Kg\ P_2O_5/ha$)				
0	1.745	24.937	50.403	33.952
30	2.441	26.572	52.155	29.509
60	2.118	27.004	71.583	34.262
90	2.357	32.617	78.454	35.891
F' test	Sig.	NS	Sig.	NS
SEm ±	0.158	2.025	7.109	3.387
CD at 5%	0.453	-	20.528	-
Levels of lime (Kg/ha)				
0	2.116	27.335	64.605	35.387
250	2.215	28.230	61.692	31.599
F' test	NS	NS	NS	NS
SEm ±	0.110	1.856	5.027	2.395
Rhizobial inoculation				
Uninoculated	2.092	27.866	61.865	31.062
Inoculated	2.232	27.699	64.432	35.745
F' test	NS	NS	NS	NS
SEm ±	0.110	1.856	5.027	2.395
CD at 5%	-	-	-	-

Uptake of calcium by seeds increased slightly from 80th day to harvest stage.

The result will be discussed while dealing with the total uptake of calcium by plants.

3.6.5 <u>Total uptake of calcium by plants</u>.

Data on the total uptake of calcium by plants are presented in Table 32 and Fig. 13 and the analysis of variance is given in Appendix XXIV.

Different levels of phosphorus applied brought about significant difference in the total uptake of calcium on the 80th day after sowing. Phosphorus applied at 90 kg P_2O_5/ha was significantly superior to the control and the treatment with 30 kg P_2O_5/ha but 60 kg P_2O_5/ha was superior to the control only. At all other stages, levels of phosphorus failed to exert any effect.

Levels of liming or rhizobial inoculation could not exert any significant effect in the uptake of calcium by plant at any of the stages. No significant interaction effect was noticed.

Total calcium uptake by plants increased with advancing age of the crop upto the 80th day but decreased substantially thereafter, the over all mean decrease at harvest as compared to the 80th day being 47.1 per cent.

Calcium uptake by plant parts showed varying trend at different levels of phosphorus applied in different plant components. For example, in the case of stem + petiole and leaves there was a general trend of increase in calcium uptake with increasing phosphorus levels. In the case of shell and seed, the trend was not consistent and was different at different stages. The increase in calcium uptake was significant in the case of stem + petiole at two stages and in the case of leaves at one stage. It is difficult to consider these significant effects as being real from an overall assessment of the trend of results. Therefore further discussion on this aspect is based on the assumption that application of phosphorus did not affect uptake of calcium. While discussing the calcium content of plant parts, it was concluded that though there was a possibility for decrease in the availability of calcium because of application of phosphorus, under the condition in which this experiment was conducted, the decrease in availability of calcium consequent to application of phosphatic fertilizers was not substantial. The data on the uptake of this nutrient by plant parts will further support this conclusion.

Application of lime did not affect the uptake of calcium by any of the plant parts at any of the stages. The reasons for similar trend in the case of calcium content and dry weight of plant parts have been discussed already. Inoculation also did not have significant effect on the calcium uptake. In as much as culture inoculation could not increase the dry matter accumulation by plant parts, there was no reason for expecting a change in the quantity of calcium taken up by plants because of this treatment.

The pattern of uptake of calcium by stem + petiole was that of a steady increase upto the 80^{th} day, followed by a substantial decrease thereafter. In the case of leaves, calcium uptake increased upto the 80^{th} day. In the shell, it remained more or less constant from 80^{th} day till harvest whereas in seed there was slight increase over the above stages. The trend of the calcium uptake either remaining constant or increasing with advancing age can be normally expected but a decrease with advancing age is not to be expected as calcium is an immobile nutrient. Such a decrease was noticed only in the case of stem + petiole from 80th day till harvest. It may be noted that there was a similar substantial decrease in the dry weight of stem + petiole also over these two stages. As was explained earlier decrease in dry weight was mainly because there was complete defoliation after the 80th day and only stem remained at the time of harvest. This loss in plant parts had their effect on calcium uptake also. In the case of total calcium uptake also, there was increase upto the 80th day followed by a substantial decrease after this stage. The extend of decrease was as much as around 47 per cent as has been explained earlier. This decrease must be accounted as due to defoliation. A point of practical importance is that in the case of soybean nearly half of the calcium taken up by plant is turned back to the soil before harvest of the crop.

While discussing the uptake of nitrogen and phosphorus the relative contribution of translocation of these nutrients to the seeds were estimated. In the case of calcium it is assumed that there was practically little translocation of this nutrient within the plants and the quantity accumulated in the seeds must have mostly come from absorption of this nutrient after formation of the seeds.

As was done in the case of nitrogen and phosphorus, an attempt is made to locate the zone of peak accumulation of calcium at the different stages. The results show that out of the total quantity of calcium accumulated in the plant on the 20^{th} day, the maximum quantity was located in leaves (55.3%), the remainder being in stem + petiole. On the 50^{th} day also the same trend continued though the relative contribution by leaves decreased to 52.1 per cent. At the next stage, 80^{th} day after sowing, the percentage contribution of leaves decreased further to 37.4 per cent. The share of total calcium uptake in stem + petiole, shell and seeds were 30.5 per cent, 21.0 per cent and 11.1 per cent respectively. At harvest, the maximum quantity of calcium was accumulated in shell (38.8%) followed closely by stem + petiole (36.3%). Seeds contributed only to 24.9 per cent of the total calcium uptake. It may be recalled that the accumulation pattern of nitrogen and phosphorus followed an entirely different pattern with the largest share of these nutrients being in seeds at the time of harvest.

Table 33. Effect of phosphorus nutrition, liming and rhizobial inoculation on total nitrogen, available phosphorus, available potassium and exchangeable calcium of soil after harvest of the crop

TREATMENTS	Total nitrogen (%)	Available phosphorus (ppm)	Available potassium (ppm)	Exchangeable calcium (ppm)
Levels of phosphorus ($Kg\ P_2O_5/ha$)				
0	0.085	1.710	206.25	427.50
30	0.086	2.793	206.88	375.75
60	0.086	3.363	192.13	350.25
90	0.082	4.099	208.75	300.50
Levels of lime (Kg/ha)				
0	0.087	3.047	203.00	367.00
250	0.083	2.936	204.00	360.00
Rhizobial inoculation				
Uninoculated	0.086	2.879	208.00	359.13
Inoculated	0.084	3.104	199.00	367.88

4. Chemical Analysis of Soil after the Harvest of the Crop:-

Data on the total nitrogen content, available phosphorus, available potassium and exchangeable calcium after the harvest of the crop are presented in Table 33.

Levels of applied phosphorus did not affect the total nitrogen and available potassium contents substantially. On the other hand, there was notable increase in available phosphorus but reverse was the effect with regard to exchangeable calcium in which case there was steady decrease with increasing levels of phosphorus.

Lack of a conspicuous change in the content of total nitrogen and available potassium with increasing levels of phosphorus and the occurance of a substantial increase in the available phosphorus content are to be normally expected. The increase in the available phosphorus content was substantial and at the highest level of applied phosphorus (90 kg P_2O_5/ha), the available phosphorus content was more than double that of control. A substantial decrease in the content of exchangeable calcium was also noted with increasing levels of phosphorus. This is in all probability because of precipitation of large quantities of calcium at higher levels of applied phosphorus. No substantial change in any of the constituents was noticed because of liming and culture inoculation. Lack of response to culture inoculation was to be normally expected and also to lime in the case of nitrogen, phosphorus and potassium contents. However, a marked increase in exchangeable calcium content was anticipated consequent to application of lime. On the contrary, in the present study, there was no indication of such an increase. The only explanation for this appears to be that all the added calcium was leached away and by the end of the crop season, the calcium level reverted back to the inherent equilibrium level. A comparison of the analysis of data of the soil with the original figures will indicate that nitrogen content did not vary much over the period of crop season, and available potassium and exchangeable calcium decreased substantially. This decrease in the content of potassium and calcium must be attributed to the heavy leaching. Phosphorus content of the soil at the end of the crop season was comparable to the initial values in the plots that did not receive phosphorus fertilizer. As mentioned earlier, plots that received phosphorus fertilizers registered a substantial increase in the content of this nutrient.

SUMMARY

S U M M A R Y

An experiment was conducted at the Instructional Farm attached to the College of Horticulture, Vellanikkara from July to October, 1978 to study the effect of phosphorus, liming and rhizobial inoculation on the growth and yield of soybean.

The growth characters, yield attributes and yield as influenced by various treatments were recorded. The nitrogen, phosphorus and calcium contents of different plant parts were also estimated. These data were statistically analysed. The results of the investigation are summarised below.

1. Different levels of phosphorus, liming and rhizobial inoculation did not exert any significant influence on the height of plants at any of the stages of observation.

2. Number of branches were also unaltered by levels of phosphorus, liming and culture inoculation either on the 50^{th} day or on 80^{th} day after sowing.

3. Levels of phosphorus did not have significant effect on leaf area index at any of the stages except

on the 20[th] day after sowing when 30 kg P_2O_5/ha was found to be superior to 60 kg P_2O_5/ha. Liming and inoculation had no effect. Significant interaction effect was noticed between phosphorus and liming on the 20[th] day when 90 kg P_2O_5 + 250 kg lime/ha recorded the highest L.A.I. value.

4. Net assumilation rate was not affected by application of phosphorus, liming or by culture inoculation at any of the stages of observation.

5. Effects of phosphorus, liming and rhizobial inoculation were not significant on dry weight of stem + petiole at all the four stages of observation. Significant interaction effect was noted between phosphorus and liming on the 20[th] day.

6. Phosphorus had significant effect on the dry weight of leaves on the 80[th] day. At this stage, 90 kg P_2O_5/ha was superior to 0, 30 and 60 kg P_2O_5/ha. Liming and culture inoculation failed to influence this character significantly. Interaction between phosphorus and liming was significant on the 20[th] day.

7. None of the factors were able to produce

significant effect on the dry weight of shell or seed at either of the stages, 80th day or at harvest.

8. Total dry weight of the plant was unaffected by phosphorus, liming or inoculation at any of the stages. However, interaction between phosphorus and liming was found to be significant at the 20th day. As in the case of dry weight of stem + petiole and leaves, maximum dry weight of the plant was obtained in treatment with phosphorus at the rate of 90 kg P_2O_5/ha in combination with 250 kg lime/ha.

9. Number and weight of root nodules did not differ because of the treatments either on the 50th day or on the 80th day after sowing.

10. Phosphorus application, liming and culture inoculation could not influence the yield components, number of pods per plant, number of seeds per pod, weight of seeds per pod and thousand seed weight.

11. Shelling percentage, harvest index and moisture percentage were unaffected by phosphorus,

liming and rhizobial inoculation. Phosphorus x lime interaction was significant with regard to shelling percentage on the 80^th^ day after sowing. Phosphorus level at 60 kg P_2O_5/ha incombination with 250 kg lime/ha gave the highest shelling percentage at this stage. The minimum value was noticed in the control.

12. Incremental doses of phosphorus had no effect in increasing the grain yield. Liming and inoculation also failed to produce significant variation.

13. Highest stover yield was produced when phosphorus was applied at 90 kg P_2O_5/ha. This level was significantly superior to all other levels of phosphorus. Application of lime or inoculation did not have significant effect. On stover yield, phosphorus x rhizobial inoculation interaction was significant. Inoculated set when given phosphorus at the rate of 90 kg P_2O_5/ha produced maximum stover yield. Minimum yield was recorded in the case where no phosphorus was applied but inoculated with rhizobium culture.

14. Application of phosphorus at the highest level of 90 kg P_2O_5/ha gave the highest percentage of nitrogen in stem + petiole on the 20th day after sowing

which was significantly superior to 30 kg P_2O_5/ha but was at par with other levels. At all other stages, levels of phosphorus had no effect on nitrogen content of these plant components. No significant effect was noticed due to liming and rhizobial inoculation.

15. No significant change in the nitrogen content of leaves, shell and seed was noticed due to phosphorus, liming or rhizobium inoculation at any of the stages of observation. But significant difference was observed due to the interaction effect ~~at harvest~~ between liming and rhizobial inoculation with regard to nitrogen content of shell. Uninoculated set, where 250 kg lime/ha was applied recorded the maximum value whereas minimum was obtained in the control plot.

16. Uptake of nitrogen by stem + petiole or leaves was not affected by phosphorus levels, lime or culture inoculation at any of the stages of observation. There was a steady increase in the uptake of nitrogen by leaves till the 80th day but in the case of stem + petiole increase was noticed only upto the 50th day which decreased thereafter till harvest.

17. Significant influence of phosphorus was

noticed on the 80th day after sowing with regard to nitrogen uptake by seeds. Phosphorus at 90 kg P_2O_5/ha gave the highest uptake value followed by 60 kg P_2O_5/ha. Both these levels were significantly superior to the control and phosphorus at 30 kg P_2O_5/ha. Phosphorus levels did not affect the uptake by seed at harvest. Uptake of nitrogen by shell on the 80th day and that at harvest were also not significantly affected by phosphorus levels. Similarly, liming or rhizobial inoculation had no effect on uptake of nitrogen by shell and seed at any of the stages. Significant interaction effect was noticed between levels of phosphorus and liming on the 80th day, with regard to nitrogen uptake by seed. Phosphorus at 90 kg P_2O_5/ha applied without lime gave the highest uptake value whereas minimum uptake of nitrogen by seed was noticed in the control. The total quantity of nitrogen translocated from different parts (stem + petiole, shell and leaves) to the grain works out to be 39 per cent remaining being directly absorbed by seeds.

18. Total uptake of nitrogen by plants on the 80th day after sowing was significantly affected by

levels of phosphorus. Highest level of phosphorus gave the maximum uptake value which decreased with decreasing levels of phosphorus. At all other stages, effect of phosphorus on this character was non-significant. Neither liming nor culture inoculation produced significant difference in total nitrogen uptake by plants at any of the stages of observation.

19. Phosphorus content of stem + petiole was not altered by levels of phosphorus, liming and rhizobial inoculation but there was significant difference due to the interaction between phosphorus levels and liming on the 80th day after sowing. Phosphorus applied at 30 kg P_2O_5/ha without lime gave highest phosphorus content in stem and petiole.

20. Different levels of phosphorus, liming and rhizobial inoculation had no effect on the phosphorus content of leaves at any of the stages. Interaction between phosphorus and liming was found to be significant on the 80th day. Lime at the rate of 250 kg/ha without phosphorus gave maximum and 60 kg P_2O_5 in combination with 250 kg lime/ha gave the minimum phosphorus content in leaves.

21. Levels of phosphorus had no effect on the phosphorus content of shell and seed either on the 80^{th} day or at harvest. In the case of seed, 250 kg lime/ha increased phosphorus content on the 80^{th} day. Effect of rhizobial inoculation was not significant. With regard to shell phosphorus content on the 80^{th} day, interaction effect between phosphorus and liming was significant. Phosphorus level at 30 kg P_2O_5/ha applied without lime recorded the maximum phosphorus content where as 90 kg P_2O_5/ha applied without lime recorded the minimum phosphorus content of shell.

22. On the 50^{th} day after sowing, uptake of phosphorus by stem + petiole was significantly affected by application of phosphorus. Highest level, 90 kg P_2O_5/ha gave highest phosphorus uptake and it decreased with decreasing levels of phosphorus applied. At the other stages, levels of phosphorus had no effect. Liming and culture inoculation also could not alter phosphorus uptake by stem + petiole. Significant interaction was found on the 80^{th} day between phosphorus and liming, when 90 kg P_2O_5 + 250 kg lime/ha gave the maximum uptake. The minimum value was recorded by the

treatment combination, 30 kg P_2O_5 + 250 kg lime/ha. Increase in uptake by stem + petiole was noted initially but it decreased in the later stage of crop growth which is attributed to be because of translocation to the seeds.

23. Phosphorus uptake by leaves was not affected by levels of phosphorus, liming or rhizobial inoculation at any of the stages. Phosphorus uptake increased till 50th day but decreased thereafter.

24. Effect of phosphorus on uptake of phosphorus by seeds was significant on the 80th day. At this stage, uptake value increased with increasing levels of phosphorus upto 90 kg P_2O_5/ha. At harvest, there was no significant difference in the phosphorus uptake by seed due to applied phosphorus. In the case of shell, uptake was unaffected by different doses of applied phosphorus. Both in the case of shell and seeds, no difference was noticed in phosphorus uptake due to liming and rhizobial inoculation. Significant interaction effect in the phosphorus uptake by seeds was observed on the 80th day. Phosphorus at 60 kg P_2O_5/ha when applied in combination with lime at the rate of 250 kg/ha recorded maximum uptake of phosphorus

in seed. On the other hand, minimum was observed in treatment with 250 kg lime/ha without phosphorus. A drop in the uptake of phosphorus by shell was noted after the 80th day till harvest but the uptake value in seeds doubled during the period. Total quantity of phosphorus translocated from different parts to the grain works out to be 64 per cent remaining being accumulated by continued uptake. Altogether seed accounted for 86.8 per cent of the phosphorus accumulated in plants at harvest.

25. As in the case of seed, 90 kg P_2O_5/ha recorded maximum total uptake of phosphorus on the 80th day after sowing it being significantly superior to control and phosphorus at 30 kg P_2O_5/ha. At all other stages, phosphorus failed to produce significant effect. Liming or culture inoculation could not significantly influence the total uptake of phosphorus. On the 50th day, interaction between levels of phosphorus and lime was significant, when control plot gave the maximum uptake value. Phosphorus and rhizobial inoculation interaction was also found to be significant. Control gave the highest value and the

combination, 60 kg P_2O_5 + 250 kg lime/ha recorded the lowest uptake.

26. Application of phosphorus failed to result in significant effect on calcium content of stem + petiole at any of the stages except on the 80th day. Here, phosphorus when applied at the rate of 60 kg P_2O_5/ha was significantly superior to control and phosphorus at 30 kg P_2O_5/ha. Of all the stages of observation, significant effect of lime was noted only at harvest where control proved to be better than lime at 250 kg/ha. Culture inoculation had no significant effect at any of the stages. Interaction between phosphorus and liming was significant on the 80th day and maximum and minimum calcium contents were noticed in treatments applied with 60 kg P_2O_5/ha without lime and treatment combination of 30 kg P_2O_5 + 250 kg lime/ha respectively.

27. Levels of phosphorus, liming and rhizobial inoculation failed to produce significant effect on the calcium content of leaves, shell and seeds at any of the stages.

28. Calcium uptake by stem + petiole was significantly altered by applied phosphorus on the 20th

day and 80th day after sowing. At both these stages, phosphorus at the highest level, 90 kg P_2O_5/ha recorded the maximum uptake. Application of lime and culture inoculation failed to exert significant effect. There was an increase in uptake by the plant part upto the 80th day which decreased conspicuously thereafter.

29. Highest level of phosphorus at 90 kg P_2O_5/ha gave the highest calcium uptake by leaves on 80th day after sowing, whereas at all other stages, it remained at par with other levels. Liming and inoculation did not have significant effect at any of the stages. Calcium uptake by leaves increased till the 80th day after sowing.

30. Uptake of calcium by shell and seeds were not affected by levels of phosphorus, liming or rhizobial inoculation at any of the stages of observation. But, interaction between phosphorus and liming was significant at harvest stage, with respect to calcium uptake of shell. Highest level of lime in combination with 60 kg P_2O_5/ha gave the highest uptake value. Calcium uptake by shell almost remained constant

from 80th day till harvest but in seeds a slight increase was noticed during the period.

31. Total uptake of calcium by plants was significant on the 20th day and 80th day after sowing. On the 20th day, phosphorus applied at 30 kg P_2O_5/ha gave maximum total calcium uptake but on the 80th day, 90 kg P_2O_5/ha recorded the highest value. Effects of liming and culture inoculation were non-significant.

32. After harvest of the crop, total nitrogen and available potassium contents of the soil did not change substantially, whereas in the case of available phosphorus a notable increase was observed. Reverse was the effect on exchangeable calcium of the soil with increasing levels of phosphorus. Liming and rhizobial inoculation did not have any conspicuous effect on any of the characters mentioned above.

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APPENDICES

APPENDIX - I

Weather data (weekly average) from 25th June to 14th October, 1978.

Date	Weeks	Temperature (°c) Maximum	Minimum	Relative humidity (%) Forenoon	Afternoon	Total rainfall (mm)	Number of rainy days.	Sunshine (hours/week)
June 25 - July 1	1	28.0	22.5	94	84	219.9	7	0.3
July 2 - July 8	2	29.0	22.9	95	81	141.8	7	1.2
July 9 - July 15	3	27.4	22.4	96	81	296.8	6	0.6
July 16 - July 22	4	29.5	23.0	93	74	46.0	7	2.9
July 23 - July 29	5	27.9	23.2	95	85	252.7	7	0.3
July 30 - August 5	6	29.3	23.3	94	79	12.5	4	1.4
August 6 - August 12	7	28.2	23.1	96	86	241.5	7	0.5
August 13 - August 19	8	28.7	22.7	95	80	127.5	7	0.4
August 20 - August 26	9	28.1	23.1	95	79	93.9	7	0.6
August 27 - September 2	10	28.1	22.5	94	81	215.5	7	1.7
September 3 - September 9	11	30.5	23.7	91	65	5.9	2	6.3
September 10 - September 16	12	30.1	23.0	91	67	11.9	2	3.7
September 17 - September 23	13	30.3	22.8	93	69	19.0	5	5.2
September 24 - September 30	14	29.7	23.1	92	70	22.9	7	2.7
October 1 - October 7	15	30.4	22.6	90	66	15.9	2	5.3
October 8 - October 14	16	31.3	23.6	92	70	8.5	2	5.7

APPENDIX - II

Analyses of variance for height of plants and number of branches

Source	df	Mean squares				
		Height of plants (cm)			Number of branches	
		20th day after sowing	50th day after sowing	80th day after sowing	50th day after sowing	80th day after sowing
Block	2	3.898	37.789	55.296	0.124*	0.152
P	3	5.071	205.115	284.852	0.058	0.033
L	1	0.028	83.029	121.858	0.002	0.069
P x L	3	0.541	8.261	23.400	0.003	0.021
I	1	0.120	0.123	5.096	0.003	0.003
P x I	3	2.778	107.084	163.824	0.015	0.013
L x I	1	3.182	168.637	197.965	0.008	0.229
P x L x I	3	1.437	12.935	54.943	0.032	0.098
Error	30	2.628	119.066	162.928	0.031	0.059

*Significant at 5 percent level

APPENDIX - III

Analyses of variance for leaf area index and net assimilation rate

		Mean squares				
		Leaf area index			Net assimilation rate ($g/m^2/day$)	
Source	df	20th day after sowing	50th day after sowing	80th day after sowing	Between 20th and 50th day	Between 50th and 80th day
Block	2	0.029	3.564	14.679**	0.224	11.733
P	3	0.027*	2.854	10.638*	0.508	2.343
L	1	0.007	0.003	0.0813	0.859	0.619
P x L	3	0.051**	0.466	0. 893	0.037	1.631
I	1	0.007	0.306	0. 178	0.001	0.0007
P x I	3	0.012	2.287	2.960	0.106	0.151
L x I	1	0.007	0.039	1.041	0.320	1.673
P x L x I	3	0.011	1.294	0.251	0.469	3.541
Error	30	0.009	1.393	2.278	0.418	3.634

* Significant at 5 percent level

** Significant at 1 percent level

APPENDIX - IV

Analyses of variance for dry weight of stem + petiole and shell of five plants

		Mean squares					
		Dry weight of stem + petiole (g)				Dry weight of shell	
Source	df	20th day after sowing	50th day after sowing	80th day after sowing	Harvest	80th day after sowing	Harvest
Block	2	0.164**	68.685	510.098*	10.058	195.969**	0.740
P	3	0.052	76.294	263.876	51.887	52.172	5.243
L	1	0.014	34.680	0.003	0.187	24.510	9.013
P x L	3	0.085*	8.206	24.214	92.769	4.766	46.357
I	1	0.050	8.167	2.430	15.870	4.750	44.468
P x I	3	0.040	26.203	98.868	11.180	18.932	7.948
L x I	1	0.004	8.003	12.000	63.740	8.250	13.653
P x L x I	3	0.014	60.816	39.087	72.284	3.156	24.606
Error	30	0.025	28.048	97.270	61.963	24.748	28.106

*Significant at 5 percent level

**Significant at 1 percent level

APPENDIX - V

Analysis of variance for dry weight of leaves and seeds of five plants

Source	df	Mean squares				
		Dry weight of leaves (g)			Dry weight of seeds (g)	
		20th day after sowing	50th day after sowing	80th day after sowing	80th day after sowing	Harvest
Block	2	0.418**	22.061*	157.163**	486.232**	13.438
P	3	0.049	9.853	83.228*	101.170	56.648
L	1	0.031	0.002	2.297	10 .083	52.083
P x L	3	0.183*	0.689	13.039	94.698	111.403
I	1	0.060	0.455	1.313	0.333	132.003
P x I	3	0.086	7.487	22.612	67.275	83.209
L x I	1	<0.001	1.367	10.823	21.870	0.563
P x L x I	3	0.053	5.874	3.275	35.414	132.773
Error	30	0.050	5.286	22.442	50.105	133.878

* Significant at 5 percent level

**Significant at 1 percent level

APPENDIX-VI

Analyses of variance for total dry weight of plants

Source	df	Mean squares			
		Total dry weight of five plants (g)			
		20th day after sowing	50th day after sowing	80th day after sowing	Harvest
Block	2	1.029**	151.927	4929.866**	9.725
P	3	0.190	136.778	1868.903	218.485
L	1	0.048	31.492	105.761	112.546
P x L	3	0.467*	14.462	42.591	718.242
I	1	0.189	14.257	3.537	392.735
P x I	3	0.198	59.805	496.009	239.650
L x I	1	0.012	15.030	0.360	166.880
P x L x I	3	0.132	102.660	175.563	637.996
Error	30	0.132	54.832	650.820	522.943

*Significant at 5 per cent level

**Significant at 1 per cent level

APPENDIX - VII

Analyses of variance for number of root nodules and weight of root nodules per plant

Source	df	Mean squares			
		Number of root nodules		Weight of root nodules	
		50th day after sowing	80th day after sowing	50th day after sowing	80th day after sowing
Block	2	0.178*	0.193*	0.003	0.017
P	3	0.071	0.080	0.0007	0.0009
L	1	0.037	0.043	0.00004	0.001
P x L	3	0.012	0.007	0.0004	0.0002
I	1	<0.001	0.067	0.0002	0.005
P x I	3	0.071	0.104	0.0006	0.012
L x I	1	0.036	0.003	0.002	0.0000008
P x L x I	3	0.008	0.009	0.0005	0.0005
Error	30	0.036	0.048	0.001	0.004*

*Significant at 5 per cent level

APPENDIX - VIII

Analyses of variance for No. of seeds/pod; weight of seeds/pod; No. of pods/plant; yield of grain and yield of stover

Source	df	Mean square				
		No. of seeds/ pod	Weight of seeds/pod	No. of pods/ plant	Yield of grain (Kg/ha)	Yield of stover (Kg/ha)
Block	2	0.003	0.535	0.009	1685722.40**	1522554.45**
P	3	0.014	0.415	0.778	176332 .24	781543.31**
L	1	0.002	0.280	0.029	17321.44	3464.29
P x L	3	0.010	1.017	1.102	130950.08	212360.84
I	1	0.001	1.417	1.892	195385.83	233839.42
P x I	3	0.003	1.432	0.870	45382.17	527611.02*
L x I	1	0.021	0.096	0.020	692.86	41225.02
P x L x I	3	0.0007	0.897	2.617	27387.87	124714.36
Error	30	0.009	1.258	1.061	106007.20	167671.53

*Significant at 5 percent level

**Significant at 1 percent level

APPENDIX IX

Analyses of variance for moisture percentage, test weight, shelling percentage and harvest index

Source	df	Mean squares				
		Moisture percentage of seeds	Test weight (g) 1000 seeds	Shelling percentage on 80th day after sowing	Shelling percentage at harvest	Harvest index
Block	2	0.299	100.700	139.966	1.742	0.002
P	3	0.443	24.225	25.919	4.906	0.003
L	1	1.330	40.900	21.333	0.117	0.00008
P x L	3	0.559	15.900	75.175*	3.962	0.0002
I	1	0.569	126.850	2.726	0.169	0.000003
P x I	3	0.286	9.200	43.938	3.429	0.002
L x I	1	0.003	45.300	11.155	2.965	0.0006
P x L x I	3	0.532	35.650	26.524	6.962	0.0003
Error	30	1.015	36.750	21.267	4.492	0.001

* Significant at 5 percent level

** Significant at 1 percent level

APPENDIX - X

Analyses variance for the nitrogen content in stem + petiole and shell

Source	df	Mean squares					
		Stem + Petiole (%)				Shell (%)	
		20th day after sowing	50th day after sowing	80th day after sowing	Harvest	80th day after sowing	Harvest
Block	2	0.679*	0.052	0.024	0.057	0.123	0.062
P	3	0.798*	0.009	0.072	0.130	0.034	0.100
L	1	0.034	0.005	0.020	0.0008	0.031	0.004
P x L	3	0.0492	0.019	0.009	0.108	0.052	0.040
I	1	0.374	0.055	0.044	0.003	0.005	0.008
P x L	3	0.189	0.021	0.065	0.036	0.006	0.016
L x I	1	0.091	0.032	0.003	0.002	0.034	0.600**
P x L x I	3	0.061	0.051	0.114	0.044	0.041	0.161
Error	30	0.224	0.057	0.082	0.063	0.112	0.052

*Significant at 5 percent level

**Significant at 1 percent level

APPENDIX - XI

Analyses variance for the nitrogen content in leaves and seeds

Source	df	Mean squares				
		Leaves (%)			Seeds (%)	
		20th day after sowing	50th day after sowing	80th day after sowing	80th day after sowing	Harvest
Block	2	0.060	0.888*	0.973*	1.135*	0.810
P	3	0.209	0.107	0.003	0.757	0.189
L	1	0.009	0.246	0.285	0.080	0.353
P x L	3	0.022	0.238	0.160	0.140	1.196
I	1	0.033	0.060	0.264	0.986	0.075
P x I	3	0.145	0.139	0.599*	0.949	0.503
L x I	1	0.170	0.009	0.520	0.213	0.246
P x L x I	3	0.177	0.535	0.558	0.026	0.399
Error	30	0.300	0.292	0.203	0.0338	0.547

* Significant at 5 percent level

APPENDIX - XII

Analyses of variance for uptake of nitrogen by stem + petiole and shell

		Mean squares					
		Stem + petiole (Kg/ha)				Shell (Kg/ha)	
Source	df	20th day after sowing	50th day after sowing	80th day after sowing	Harvest	80th day after sowing	Harvest
Block	2	0.210	39.108	152.834	24.617	557.168**	35.442
P	3	0.374	66.773	100.811	72.209	62.545	1.213
L	1	0.001	19.298	14.354	44.152	97.840	1.771
P x L	3	0.505	18.006	2.713	33.860	19.480	25.250
I	1	0.020	31.457	23.020	9.343	0.042	13.674
P x I	3	0.260	19.026	11.712	3.752	43.326	7.451
L x I	1	0.143	1.000	12.097	1.209	7.107	13.251
P x L x I	3	0.007	31.352	41.197	34.665	7.501	6.851
Error	30	0.208	65.176	99.589	35.318	83.320	16.973

*Significant at 5 percent level

**Significant at 1 percent level

APPENDIX - XIII

Analyses of variance for the uptake of nitrogen by leaves and seeds

		Mean squares				
		Leaves (Kg/ha)			Seeds (Kg/ha)	
Source	df	20th day after sowing	50th day after sowing	80th day after sowing	80th day after sowing	Harvest
Block	2	6.281**	45.388	1626.907**	19197.492**	1734.768
P	3	0.617	172.429	464.322	5281.034*	346.312
L	1	0.583	0.126	15.708	106.056	12.271
P x L	3	2.743	26.630	117.122	3887.276*	7529.429
I	1	0.939	18.500	13.104	209.677	2302.562
P x I	3	2.306	54.489	57.933	1404.016	5155.252
L x I	1	0.183	44.583	426.974	156.762	137.871
P x L x I	3	1.333	120.841	138.518	709.237	3360.458
Error	30	1.149	114.690	206.872	1211.848	3657.378

*Significant at 5 percent level

**Significant at 1 percent level

APPENDIX XIV

Analyses of variance for total uptake of nitrogen by plants

Source	df	Mean squares			
		Total uptake of nitrogen by plants (Kg/ha)			
		20th day after sowing	50th day after sowing	80th day after sowing	Harvest
Block	2	6.546*	78.754	43175.147**	2129.379
P	3	1.651	380.151	11689.475*	2341.033
L	1	0.156	87.264	115.630	2307.136
P x L	3	4.166	43.144	2800.936	5254.700
I	1	0.200	21.200	1013.657	2817.961
P x I	3	2.724	258.150	3278.590	2779.017
L x I	1	0.128	207.333	105.613	434.644
P x L x I	3	0.611	346.927	948.854	4016.221
Error	30	1.763	290.302	2876.344	4130.621

*Significant at 5 percent level

**Significant at 1 percent level

APPENDIX - XV

Analyses of variance for the phosphorus content of stem and petiole and shell

Source	df	Mean squares					
		Stem + petiole (%)				Shell (%)	
		20th day after sowing	50th day after sowing	80th day after sowing	Harvest	80th day after sowing	Harvest
Block	2	0.003	0.004	0.001	0.002	0.0005	0.001
P	3	0.003	0.001	0.001	0.006**	0.003	0.0007
L	1	0.003	0.001	<0.001	0.0003	0.001	0.0002
P x L	3	0.005	0.002	0.010*	0.0004	0.009*	0.002
I	1	0.00007	0.00005	0.002	0.00008	0.000002	0.002
P x I	3	0.0002	0.0007	0.003	0.0005	0.001	0.002
L x I	1	0.004	0.00002	0.006	0.0001	0.007	0.0002
P x L x I	3	0.0004	0.001	0.0006	0.0004	0.002	0.0001
Error	30	0.004	0.002	0.003	0.0008	0.003	0.001

*Significant at 5 percent level

**Significant at 1 percent level

APPENDIX XVI

Analyses of variance for the phosphorus content of leaves and seeds

Source	df	Mean squares				
		Leaves (%)			Seeds (%)	
		20th day after	50th day after	80th day after	80th day after	Harvest
Block	2	0.004	0.065**	0.007	0.040	0.007
P	3	0.023	0.013	0.005	0.027	0.030
L	1	0.009	0.030	0.00008	0.098*	0.007
P x L	3	0.003	0.010	0.017**	0.44	0.015
L	1	0.030	0.0000008	0.0008	0.006	0.00002
P x I	3	0.006	0.016	0.007	0.053	0.022
L x I	1	0.040	0.008	0.002	0.031	0.002
P x L x I	3	0.008	0.003	0.001	0.006	0.008
Error	30	0.013	0.011	0.003	0.020	0.021

*Significant at 5 percent level

**Significant at 1 percent level

APPENDIX-XVII

Analyses of variance for uptake of phosphorus by stem + petiole and shell

Source	df	Mean square					
		Stem + petiole (Kg/ha)				Shell (Kg/ha)	
		20th day after sowing	50th day after sowing	80th day after sowing	Harvest	80th day after sowing	Harvest
Block	2	0.004	1.495	5.494	0.111	5.736*	0.023
P	3	0.001	3.774*	3.426	0.099	1.543	0.052
L	1	0.002	0.670	0.182	0.147	0.022	0.032
P x L	3	0.001	0.915	6.050**	0.255	1.000	0.052
I	1	< 0.001	0.882	2.050	0.015	0.002	0.006
P x I	3	< 0.001	1.174	2.224	0.374	0.056	0.354
L x I	1	0.003	1.125	0.672	0.329	0.383	0.090
P x L x I	3	< 0.001	3.185	0.767	0.207	0.722	0.064
Error	30	0.002	1.203	1.856	0.356	1.259	0.394

*Significant at 5 percent level

**Significant at 1 percent level

APPENDIX - XVIII

Analyses of variance for uptake of phosphorus by leaves and seeds

		Mean squares				
		Leaves (Kg/ha)			Seeds (Kg/ha)	
Source	df	20th day after sowing	50th day after sowing	80th day after sowing	80th day after sowing	Harvest
Block	2	0.050	13.630**	8.008*	115.644**	13.440
P	3	0.013	4.341	3.893	31.786*	39.918
L	1	0.011	2.562	0.390	8.763	1.686
P x L	3	0.005	0.868	3.137	30.770*	2.571
I	1	0.021	0.193	0.076	0.490	25.748
P x I	3	0.006	4.596	1.161	8.239	10.019
L x I	1	0.032*	1.767	0.005	26.151	16.212
P x L x I	3	0.005	1.914	0.610	4.317	54.054
Error	30	0.007	1.844	1.595	9.739	39.377

*Significant at 5 per cent level

**Significant at 1 per cent level

APPENDIX - XIX

Analyses of variance for total uptake of phosphorus by plants

Source	df	Mean squares: Total uptake of phosphorus by plants (Kg/ha) — 20th day after sowing	50th day after sowing	80th day after sowing	Harvest
Block	2	0.018	8.291	284.766**	14.753
P	3	0.008	10.703	111.243*	38.020
L	1	0.007	2.301	3.038	2.642
P x L	3	0.016	30.515*	17.243	2.995
I	1	0.030	6.872	7.497	25.148
P x I	3	0.010	34.375*	3.207	12.592
L x I	1	0.009	2.417	47.772	25.886
P x L x I	3	0.005	42.500*	17.509	65.112
Error	30	0.012	9.548	34.214	46.529

*Significant at 5 per cent level

**Significant at 1 per cent level

APPENDIX - XX

Analyses of variance for the calcium content of stem + petiole and shell

		Mean squares					
		Stem + petiole (%)				Shell (%)	
Source	df	20th day after sowing	50th day after sowing	80th day after sowing	Harvest	80th day after sowing	Harvest
Block	2	0.222	0.367**	0.113*	0.216**	0.092	0.040
P	3	0.232	0.008	0.149**	0.001	0.014	0.109
L	1	0.001	0.083	0.019	0.218**	0.031	0.064
P x L	3	0.081	0.001	0.072*	0.043	0.029	0.110
I	1	0.194	0.058	0.002	0.022	0.006	0.057
P x I	3	0.134	0.055	0.012	0.006	0.018	0.090
L x I	1	0.011	0.025	0.021	0.010	0.019	0.018
P x L x I	3	0.070	0.089	0.022	0.024	0.099	0.174
Error	30	0.108	0.056	0.023	0.021	0.068	0.070

*Significant at 5 per cent level

**Significant at 1 per cent level

APPENDIX - XXI

Analyses of variance for the calcium content of leaves and seeds

Source	df	Mean squares: Leaves (%) 20th day after sowing	50th day after sowing	80th day after sowing	Seeds (%) 80th day after sowing	Harvest
Block	2	0.538*	0.740**	1.383**	0.011	0.010
P	3	0.241	0.089	0.367	0.050	0.009
L	1	0.006	0.035	0.090	0.005	0.001
P x L	3	0.117	0.270	0.172	0.010	0.019
I	1	0.101	0.114	0.052	0.004	0.023
P x I	3	0.067	0.205	0.043	0.021	0.006
L x I	1	0.012	0.095	0.465	0.002	0.009
P x L x I	3	0.167	0.014	0.035	0.028	0.012
Error	30	0.146	0.120	0.159	0.030	0.014

*Significant at 5 per cent level

**Significant at 1 per cent level

APPENDIX - XXII

Analyses of variance for uptake of calcium by stem + petiole and shell

Source	df	Mean squares: Stem + petiole (Kg/ha): 20th day after sowing	50th day after sowing	80th day after sowing	Harvest	Shell (Kg/ha): 80th day after sowing	Harvest
Block	2	0.183	13.459	382.523**	39.000	83.510	13.075
P	3	0.253*	31.801	235.959*	31.910	45.225	36.702
L	1	0.071	0.291	2.608	80.005	47.840	0.943
P x L	3	0.108	3.936	87.639	73.614	5.416	93.517*
I	1	<0.001	0.559	6.847	1.691	9.505	76.583
P x I	3	0.159	17.110	14.979	14.601	18.756	4.711
L x I	1	0.055	2.920	29.031	19.750	47.481	40.168
P x L x I	3	0.050	62.343	2.085	35.680	32.934	53.085
Error	30	0.081	27.907	64.077	32.851	26.282	22.049

*Significant at 5 per cent level

**Significant at 1 per cent level

APPENDIX - XXIII

Analyses of variance for uptake of Calcium by leaves and seeds

Source	df	Mean squares				
		Leaves (Kg/ha)			Seeds (Kg/ha)	
		20th day after sowing	50th day after sowing	80th day after sowing	80th day after sowing	Harvest
Block	2	0.121	106.195*	1116.495**	82.255**	8.281
P	3	0.298	42.900	556.567*	10.360	0.763
L	1	0.014	6.519	0.030	1.526	20.619
P x L	3	0.334	10.654	97.232	15.967	0.837
I	1	0.221	1.813	9.837	0.006	38.020
P x I	3	0.094	43.077	15.884	15.128	16.096
L x I	1	0.009	1.212	53.109	2.430	4.477
P x L x I	3	0.271	16.584	106.789	11.498	27.435
Error	30	0.128	20.323	165.667	13.647	13.562

*Significant at 5 per cent level

**Significant at 1 per cent level

APPENDIX - XXIV

Analyses of variance for total uptake of calcium by plants

Source	df	Mean squares			
		Total uptake of calcium by plants (Kg/ha)			
		20th day after sowing	50th day after sowing	80th day after sowing	Harvest
Block	2	0.497	179.021	4638.587**	145.525
P	3	1.164*	134.164	2354.824*	89.584
L	1	0.116	9.630	101.821	156.349
P x L	3	0.815	21.573	47.232	328.145
I	1	0.255	0.336	79.130	263.062
P x I	3	0.342	72.266	125.607	42.350
L x I	1	0.014	0.371	337.981	166.470
P x L x I	3	0.509	122.362	159.235	176.005
Error	30	0.296	82.696	606.404	137.701

*Significant at 5 per cent level

**Significant at 1 per cent level

EFFECT OF PHOSPHORUS NUTRITION, LIMING AND RHIZOBIAL INOCULATION ON SOYBEAN [*Glycine max* (L.) Merrill]

BY

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ABSTRACT OF A THESIS
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ABSTRACT

An experiment was conducted at the Instructional Farm attached to the College of Horticulture, Vellanikkara during July to October 1978, to study the effect of phosphorus nutrition, liming and rhizobial inoculation on soybean (Glycine max (L.) Merril).

The investigation was taken up with the objective of arriving at the phosphorus requirement of the crop, assessing the response to liming and evaluating the effect of rhizobial inoculation. The trial was also aimed at studying the possible interaction effects between these factors.

The experiment was laid out as a factorial in randomised block design with 16 treatments and 3 replications.

The study revealed that applied phosphorus did not significantly affect any of the growth characters consistently. Grain yield and yield attributes were also unaffected but stover yield increased with higher doses of applied phosphorus.

In general, nitrogen, phosphorus and calcium contents in plant components were unaffected by levels of phosphorus,

liming and rhizobial inoculation. Uptake of these nutrients also remained almost unchanged. At harvest, nitrogen uptake by seeds constituted 44 per cent of the total, remaining being accumulated in stem + petiole and shell. In the case of phosphorus, 86.9 per cent of the total accumulation was in seeds, 6.0 per cent and 7.1 per cent being in stem + petiole and shell respectively. Calcium being an immobile nutrient and an element not translocated within the plant, proportion of uptake of calcium in various components of the plant was different from that of nitrogen and phosphorus. In contrast to nitrogen and phosphorus, only 24.9 per cent of the total was found in seeds whereas 36.3 per cent and 38.8 per cent of it were concentrated in stem + petiole and shell respectively.

Levels of phosphorus, had no effect on total nitrogen and available potassium contents of soil after harvest of the crop but there was a notable increase in available phosphorus and decrease in exchangeable calcium. Liming and rhizobial inoculation did not have any conspicuous effect on the content of nutrients in soil.