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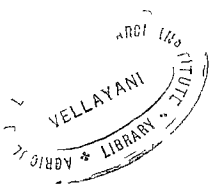
THE EFFECT OF APPLICATION OF PHOSPHATE TO LEGUMES ON THE GROWTH AND YIELD OF THE SUCCEEDING RAGI CROP (*Eleusine coracana*)



BY

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THESIS

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C E R T I F I C A T E

This is to certify that the thesis herewith submitted contains the results of bona fide research carried out by Shri.P.J. Ittyaverah under my supervision. No part of the work embodied in this thesis has been submitted earlier for the award of any degree.

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10th August, 1964.

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INTRODUCTION

The soil is the principal reservoir of plant nutrient phosphorus. It is present in the soil as mineral deposits and in the form of plant and animal residues. Indian soils are generally poor in phosphorus and deficiency is rather widespread. The average total P_2O_5 content of Indian soils is 0.102 per cent and the available P_2O_5 content is 0.021 per cent (Las,S. 1945). It is clear from these figures that very little of the total reserves of soil phosphate is available for growing crops. The phosphorus status of the soils of Kerala is even more unsatisfactory. Results of fertility surveys and soil test data on about 50,000 samples reveal that over 80 per cent of the cultivated soils in the State are very deficient in this critical plant food. It is thus obvious that these soils badly need phosphorus and liberal phosphate fertilization is absolutely essential if better crop yields are to be secured.

Even in soils containing large amounts of total phosphorus plants may frequently exhibit a deficiency of this element. This anomalous behaviour is due to the phenomenon known as phosphate reversion or 'fixation'. Fixation of phosphorus in soils is influenced by various factors. Of these factors, the presence of hydrous oxides of iron and aluminium, high acidity, low phosphorus status

of the soil, and depletion of calcium are mainly responsible for the fixation of this nutrient under Kerala conditions. The problem of phosphate fertilization is therefore far more serious in Kerala than in most other parts of India.

The fixation of added phosphates in the soil should be reduced to the minimum for better utilisation of this element by crops. Of the various methods recommended to combat fixation, supply of phosphate in conjunction with organic matter appears very promising. The increased availability of phosphorus when applied along with organic matter is attributed to:

i. The formation of phosphohumic complexes that are more easily assimilable by plants.

ii. Anion replacement of the phosphate by the humate ion.

iii. The coating of sesquioxide particles by humus, forming a protective cover and thus reducing the phosphate fixing capacity of the soil.

It has recently been suggested that the acids formed during the decomposition of organic matter will form stable complexes with iron and aluminium, thereby preventing their reaction with phosphate, and also by releasing previously fixed phosphates for plant use. (Struthers and Siebing 1950).

Application of phosphates through leguminous green manure crops is considered a still better method of enhancing phosphate availability in the soil. As reported by De Turk (1942) legumes have the unique capacity to utilise insoluble forms of phosphorus. Further, the application of phosphate to leguminous green manure crops stimulates root nodule bacteria and fixation of nitrogen with consequent enrichment of the soil (Khan, Bajpai and Mathur 1954). This is all the more important under Indian conditions because of the poor nitrogen and organic matter status of our soils. The average level of nitrogen in the soils of this country is about 0.05 per cent as against 0.14 per cent in temperate regions. Likewise, organic carbon content of our soils is of the order of 0.6 per cent as against 3.0 per cent in Europe.(Mariakulandai 1961).

The application of phosphates in conjunction with leguminous gree manure crops not only increases the nitrogen status of the soil, but also enhances the availability of phosphorus for the benefit of the succeeding crops. This has been established by several investigators like Venkata Rao and Govindarajan (1960), Singh (1961) and Rao et al.(1962). Though considerable research has been carried out in India on phosphate manuring in conjunction with leguminous green manure crops, on different soils, very little information is available with respect to the laterite and red soils of Kerala. Green manure crops commonly grown differ considerably in their

ability to take up phosphorus and make it available for succeeding crops. In the light of the above observations, the present investigation was undertaken with the following two main objectives:

i. To study the effect of application of phosphate to leguminous green manure crops.

ii. To determine the comparative efficiency of different legumes grown in Kerala in increasing the availability of phosphorus and enhancing symbiotic nitrogen fixation.

It is hoped that the results of this study will help in formulating sound recommendations for the better utilisation of phosphates by indirect application through legumes.

REVIEW OF LITERATURE

Importance of legumes in soil fertility:

From time immemorial legumes have been recognised as soil enrichers. According to Cook and Miller (1944), Columella a Roman agriculturist of the first century, advised the farmers to raise lupins to enrich the soil. The role of bacteria as nitrogen fixers, found in the nodules of legumes was recognised in 1886. Hillreigal and Wilfarth (1886) and Beijerinck (1888) started systematic research on nitrogen fixation by legumes. (quoted by Cook and Miller 1944). They proved that leguminous plants are able to obtain atmospheric nitrogen for their growth, development and seed production in symbiotic relationship with specific bacteria growing in the root nodules.

Collesson (1933) found that the nitrogen fixing capacity of alfalfa ranged from 188 to 260 pounds per acre per year. Lyon and Bizzell (1934) found that the amount of nitrogen fixed by various legumes varied considerably. It ranged from 48 pounds per acre per year through field beans to 251 pounds through alfalfa. Buckman and Brady (1960) estimating the quantity of nitrogen fixed by clover reported the figures as 100 to 150 pounds per acre.

Another fact worthy of consideration regarding legumes is their ability to utilise relatively insoluble phosphatic minerals from the soil. De Turk (1942) reported that sweetclover

was capable of rapidly utilising phosphate directly from rock phosphate, a phenominon which cereals like wheat and corn failed to accomplish.

Growth and yield of legumes as influenced by phosphates:

As pointed out by several investigators, phosphate plays an important role in increasing the yield and dry matter content of legumes.

Wing (1913) observed that growth of alfalfa markedly increased by phosphate fertilization. Truesdell (1917) proved that fertilization of alfalfa with phosphate resulted in rapid growth in seedling stage.

Fellers (1918) reported striking increase in yield and dry matter content in Canada field beans, by the application of phosphate. Increased yield and dry matter content in Canada field beans, by application of phosphate was reported by Mc Taggart (1921). Rao (1922-23) concluded from experiments carried out at Mysore, that daincha (Sesbania aculeata) showed better growth by the application of super phosphate.

Blaser, Volk and Smith (1941) and Stitt (1944) obtained better growth in clover, with phosphate fertilization. Robinson (1944) showed that the yield and dry matter production in alfalfa were increased by application of acid phosphate.

Parr and Bose (1947) reported that application of super phosphate produced luxuriant growth in berseem, and more than doubled the yield. This was subsequently confirmed by the

same workers in 1948.

Sen and Bains (1951) found that among phosphatic fertilizers viz. ammonium phosphate, super phosphate, basic slag and bone meal, best response was shown by ammonium phosphate. Celino (1950) reported that the growth and green matter production of alfalfa and red clover showed considerable increase due to phosphate fertilization, when grown in clay loam soils of pH 5.9 in Phillippines.

Ramaiah (1952) recorded an increase in yield of green matter of sannhemp due to the application of super phosphate. Sen and Rao (1953) reviewing work done in India on phosphate fertilization of legumes, reported that in soils where the phosphoric acid status was low, there was marked response to phosphate application in the growth of cow pea, sannhemp and daincha.

Bureau (1953) proved that application of super phosphate at the rate of 50 pounds P_2O_5 per acre increased the yield and dry matter production of soybeans.

Rao et al. (1954) found that phosphate manuring of berseem at the rate of 60 pounds P_2O_5 per acre increased the yield considerably.

Raychaudhari and Subbaiah (1954) reported that the application of phosphate especially to winter legumes, resulted in the improvement of their yields.

Crofts (1954) observed that application of 4 cwts. of super phosphate per acre showed considerable increase in the yield of garden pea.

Howell (1954) found that soybeans had grown taller and produced higher yields, by the increase in phosphate level from 2-10 parts per million in nutrient solution.

Singh and Verma (1954) observed that application of phosphatic fertilizers at the rate of 198 pounds P_2O_5 per acre increased the yield of berseem on all the three cuttings.

Chandanani and Oberoi (1956) and Khan and Mathur (1957) in their studies on manuring of sannhemp with super phosphate at the rate of 80 pounds per acre recorded an increase in yield of green matter to an extent of 3.5 cwt. per acre.

On similar studies by Rao et al.(1957) the yield and dry matter content of sannhemp were found to be increased by the application of super phosphate, at the rate of 80 pounds and 160 pounds P_2O_5 per acre.

Verghese et al.(1957) reported that manuring of Crotalaria striata with super phosphate at the rate of 60 pounds phosphoric acid per acre increased the yield of green matter upto 26 per cent over control.

Sikka and Jain (1958) reported that phosphate and micronutrients like boron and molybdenum increased the green matter yield of guar by about 31 per cent over control.

Eksten and Beyers (1958) concluded that phosphate fertilization increased the yield of lupins considerably.

Rao and Sankar (1960) in their investigations on phosphate manuring the sannhemp concluded that the application of super phosphate at the rate of 80 pounds P_2O_5 per acre increased the green matter yield considerably.

In an experiment to study the effect of rock phosphate and super phosphate on height, weight of lopping and fresh and dry weight of shoot and roots of Crotalaria anagyroids, Datta and Sharma (1961) reported that the application of super phosphate at the rate of 90 kilograms P_2O_5 per hectare had a pronounced effect on the growth of the crop. The effect of super phosphate was significantly superior to finely ground rock phosphate on equal phosphate basis.

Ballal and Natu (1961) reported that application of P_2O_5 to groundnut crop showed increase in the yield of the crop. The response of groundnut per pound of P_2O_5 for three doses of 10, 20 and 30 pounds per acre came to 18.9, 11.1 and 7.1 pounds respectively.

Sen, Bains and Mathur (1962) found that fodder legumes like senji and berseem showed marked increase in yield due to

the application of super phosphate. Of pulses, peas responded significantly, whereas gram showed only little response.

Rao et al.(1962) observed that application of super phosphate to green manure crops like phillipesara, sannhemp and indigofera at the rate of 22.5 pounds P_2O_5 per acre showed considerable increase in green matter yield.

Sen (1963) in his investigation on building up to soil fertility through phosphate manuring of legumes under irrigated conditions, showed that the application of super phosphate to berseem increased the green matter production. Best results were obtained with 72 Kilograms of P_2O_5 per hectare.

Some investigators failed to get any response to phosphate fertilization of legumes.

Desai, Rao and Rao (1957) found that phosphate manuring of green manure crops in sandy loams with available P_2O_5 content of 50 pounds per acre had no effect on green matter production.

Nair et al.(1957) failed to obtain any significant increase in green matter production in Sesbania speciosa by the application of phosphoric acid singly at the rate of 30 pounds per acre.

Investigations carried out by Relwani and Ganguly (1959), on green manuring in conjunction with application of

fertilizers, indicated that the response shown by daincha to the application of super phosphate was not significant.

Influence of phosphate on nodulation of legumes:

Application of phosphate has shown to have marked influence on nodule formation of legumes, by several workers. Wholtman and Bergene (1902) concluded that while potassium phosphate stimulated nodulation, ammonium sulphate had the opposite effect of supressing nodule formation in alfalfa.

Eichinger (1913) and Wilson (1917) found that super phosphate stimulated nodule formation in soybeans.

Prucha (1915) observed good nodulation in field beans, when small quantities of potassium acid phosphate and calcium monobasic phosphate were applied.

Truadell (1917) proved that phosphate fertilization of alfalfa resulted in increased nodulation. Helz and Whiting (1928) concluded that phosphatic fertilizers increased nodulation in soybeans, when applied in quantities which were not inhibitory to germination.

Swell and Gainey (1930) demonstrated that in soil deficient in lime, application of super phosphate were more beneficial in inducing nodulation in alfalfa, than application of calcium alone.

Franklin, Davis and Brewar (1940) carried out

experiments with phosphate manures on innoculated vetch and Australian peas. They held that "since the nodule organisms are associated with legumes, which relatively use larger quantities of calcium and phosphorus, they are adopted to a comparatively high level of calcium and phosphorus nutrition".

Ludeke (1941) found that increasing the amount of phosphorus increased the number of nodules in soybeans.

Smith (1944) observed that application of super phosphate stimulated the production of large number of healthy well developed nodules in clover.

Celino (1950) reported that phosphate fertilization of alfalfa and redclover showed considerable increase in nodulation and nitrogen content of plants.

Khan, Bajpai and Mathur (1954) and Sen and Bains (1955) found that application of super phosphate to berseem increased the number of healthy nodules.

Nair et al.(1957) concluded that application of super phosphate increased the number of nodules on Sesbania speciosa under Kerala conditions.

Phosphate and nitrogen fixation of legumes:

Ample evidence has been obtained from large number of experiments conducted all over the world to show that phosphates stimulate nitrogen fixation by legumes. Several

workers proved that due to phosphate fertilization, the increase in nitrogen fixation takes place, not only due to increased growth of the crop, but also due to the increase in percentage of nitrogen in the plant material.

Truesdell (1917) found that phosphate fertilization of alfalfa crop increased the total nitrogen fixed, through increased yields, and the increase in the nitrogen content of the plant material.

Fellers (1918) reported that, the protein content of soybeans increased with the application of super phosphate.

Mc Taggart (1921) proved that phosphates were responsible for increasing the total nitrogen in the soil, and the percentage of nitrogen in the plant material of soybeans and alfalfa.

Ludulke (1941) noted that the amount of nitrogen fixed by legumes increased considerably in presence of phosphorus.

Sammet (1942) observed that the development of bacteria and fixation of nitrogen by nodules of soybeans, increased with the increased application of phosphate.

James et al. (1944) reported uniform increase in the rate of growth and quantity of nitrogen fixed by legumes due to phosphate application.

Parr and Bose (1945) found that since the amount of nitrogen fixed is proportional to their yields, the application

of phosphates to legumes, increased their nitrogen fixing capacity.

Mercer (1948) claimed that "the cheapest method of supplying nitrogen is by stimulating the growth of legumes with phosphate fertilizers".

Fisher, Sammet and Poschenriedar (1950) showed that phosphate fertilization favoured the formation of nodule and led to increased nitrogen fixation by legumes. The uptake of nitrogen was simultaneously increased, which resulted in an increase in nitrogen content in all plant parts. Further they noted that the quantity of atmospheric nitrogen assimilated by the nodule was highest with phosphate application.

Vyas (1953) concluded that all the phosphatic manures tried increased the nitrogen content of pea plants; the increase in nitrogen percentage over control being 47.6 percent, 35.5 percent, 24.8 percent and 18.4 percent for super phosphate, Trichy nodule phosphate, Singhhum phosphate and bone meal respectively.

Acharya, Jain and Jha (1953) found that where berseem was grown in rotation, manured with super phosphate had 40 percent more nitrogen after ten years, and 17 percent where berseem was grown without phosphate, over the control of continuous cropping.

Vyas and Desai (1953) studied the effect of phosphate on nitrogen fixation by pea plants. Two doses viz. 60 pounds and 120 pounds of phosphoric acid were utilised for the trial. They reported a significant increase equal to 51.7 percent and 109.0 per cent in the quantity of nitrogen fixed in aerial parts of the plant by the two doses respectively. However the increase in the quantity of nitrogen in the soil was not significant, where the aerial parts were not incorporated as compared with pre legume soil nitrogen value.

Influence of phosphate manuring of green manures on succeeding crops.

Investigators all over the world found that phosphate fertilization of legumes has considerably increased the yield of succeeding crops.

Taylor and Ghose (1922) found that application of super phosphate to daincha (Sesbania aculiata) not only increased the green matter production, but also improved the yield of succeeding paddy crop. The effect of super phosphate was found to be more conspicuous than bone meal as shown by the yield of daincha as well as the succeeding paddy crop.

Hutchings (1936) observed that phosphate fertilization of legumes represented a higher level of fertility as indicated by the yield of the succeeding crop.

Parr and Bose (1947) concluded that wheat grown in plots to which phosphate had been applied to berseem in previous years,

produced 100 percent more yield than wheat followed by unmanured berseem.

Parr and Sen (1948) showed that in the permanent manurial trials conducted for a period of 36 years, green manuring with sannhemp in conjunction with super phosphate recorded the highest yield.

Sen and Bains (1951) observed that phosphate fertilization of berseem at the rate of 120 pounds of superphosphate per acre, increased the yield of succeeding wheat and maize crops.

Khan (1952) recorded higher yields in paddy, maize and wheat by indirect application of phosphate through berseem. Ramiah (1952) reported increased rice yields at Irvin canal farm in Mysore and Labhaudhi farm in Madhya Pradesh by phosphate fertilization of preceding sannhemp crop.

Govindarajan and Venkata Rao (1952) obtained significant increase in rice and ragi yields, by applying 56 to 112 pounds of bone meal to the preceding green manure crop.

Mirchandani and Khan (1952) while reviewing the works done all over India on phosphate manuring of green manure observed that in Bihar green manure plus super phosphate at the rate of 224 pounds per acre gave 96 percent increase in paddy yield over no manure, while it was only 18 percent when green manuring alone was done. In Orissa an increase of

37.8 percent in the yield of paddy was obtained when green manuring was done in conjunction with P_2O_5 at the rate of 32 pounds per acre over no manure control, while in the case of green manuring alone it was 34.9 percent. In Madras also green manure plus super phosphate at the rate of 50 pounds P_2O_5 per acre gave an increase of 25.7 percent over no manure, while it was only 2.9 percent in the case of green manure alone.

Sen and Rao (1953) found that the yield of wheat increased as a result of indirect application of phosphate through sannhemp. Application of 120 pounds of super phosphate through sannhemp produced 36.6 percent increase in yield than green manure alone.

Khan, Bajpai and Mathur (1954) reported that maize and wheat grown in rotation with berseem fertilised with phosphate at the rate of 120 pounds super phosphate per acre, showed higher yields than from plots rotated with unfertilised berseem.

Raychaudhuri and Subbiah (1954) found that application of phosphate to winter legumes, not only resulted in the improvement in yield and quality of the directly manured crop, but beneficial effects could be noticed on succeeding cereal crops also.

Chandnani and Oberoi (1955) reported significant residual effect for different forms of phosphates on legumes, which

was manifested by the increased yields of succeeding crops.

While reviewing the reports of the Model Agronomic experiments conducted at various centres during Rabi 1957/58 and succeeding Kharif 1958, it had been found that, the residual effect of legumes grown varied differently, while the residual effect of the phosphate applied through legumes responded significantly on the succeeding crop. (Annonymous 1957-58 and 1958).

Venkata Rao and Govindarajan (1960) showed that application of green manure alone produced marked increase in the yield of both grain and straw in ragi. The application of phosphorus alone through green manure further increased the yield.

Singh (1961) reported that application of super phosphate to legumes at the rate of 40 pounds P_2O_5 per acre, increased the yield of the succeeding wheat crop.

Kanwar (1962) found that phosphate fertilization of berseem at the rate of 20 pounds P_2O_5 per acre not only increased its yield, but the succeeding maize crop was highly benefited as indicated by higher yields.

Rao et al.(1962) established that application of super phosphate to leguminous green manure crops at the rate of 22.5 pounds P_2O_5 per acre was more advantageous than direct application to paddy.

Patel, Ghosh and Sen (1963) concluded that application of super phosphate to berseem at the rate of 72 kgs. per hectare increased the yield of succeeding wheat crop.

Contrary to the previous findings in 1951, Sen and Baine (1956) found that the application of 80 pounds P_2O_5 per acre through cow pea showed no beneficial effect on succeeding wheat. Direct application of superphosphate increased the yield of wheat by about 16 percent over the same quantity applied through cow pea, which was as good as no manure control.

Experiments conducted by the Division of Agronomy, Agricultural College and Research Institute, Coimbatore (1956-57) revealed that indirect application of phosphate to paddy through leguminous green manure crops did not give any significant beneficial effect (Annonymous 1956-57).

Sen, Baine and Mathur (1962) reported that direct application of phosphate to cereals was superior to indirect manuring through legumes, except in the case of berseem, which compared favourably with direct manuring.

Response of cereals to phosphorus.

The relationship of phosphorus to growth has long been recognised, but its important role in plant life is being fully realised only recently. This element has long been known as a constituent of nuclic acid, phytin and

phospholipids. It is associated with early maturity of crops, particularly cereals and a shortage of this element is manifested by a marked reduction in plant growth.

Of the three essential plant nutrients, next to nitrogen, phosphorus is found to be very important. Sethi (1959) estimated that 60 percent of the agricultural soils in India do not contain high reserve of phosphorus and out of the total quantity of nutrients present only one-fifth is available to plants.

Sircar and Sen (1941) growing paddy at three levels of phosphorus found that greatest intake of nitrogen was associated with highest phosphorus level. Brenes, Miller and Schnehl (1955) and Grones et al (1958) reported that the absorption of phosphate was stimulated by the presence of nitrogen.

Phosphorus is known to influence the development of roots, maturation of crops and the composition of the crop in general. Noll, as quoted by Collings (1954) found that phosphorus hastened maturity of small grains and corn in Pennysilvania Experiment Station. Panikkar (1958) reported that Indian soils are deficient in phosphorus and recorded positive results on phosphate fertilization of sorghum.

In paddy there are several experiments to prove the positive response of phosphoric acid invariably in combination

with nitrogen. Raheja (1960) in discussing the simple fertilizer trials conducted on paddy and the respective response of the crop to both nitrogen and phosphoric acid stated that at 40 pounds per acre level, the response to phosphoric acid and nitrogen was 1.5 times more than that at 20 pounds per acre levels. The response to a combination of 20 pounds nitrogen and 20 pounds phosphoric acid per acre was almost equal to 40 pounds nitrogen alone per acre in paddy and wheat. Further, results as reported by Okada (1931) prove the efficiency of phosphoric acid for accelerating the absorption of nitrogen by rice and thus hastening the maturity.

However, there are several parallel findings also showing partial or total lack of response to phosphoric acid fertilization. Stewart (1947) discussing the manurial experiments in India, observed that numerous experiments of broadcast dressings of phosphate fertilizers have failed to show a response in yield, but many conflicting results obtained showed that shallow rooted crops responded better than the deep rooted crops. He also recorded that in many instances though phosphate alone had little response on yield, its combination with nitrogen might be markedly superior to nitrogen alone.

Chin (1958) stated that the response of paddy to phosphoric acid was little significant in red soils low in P_2O_5, but there was little response on alluvial soils higher in phosphorus. Takijima, Shiojima and Konno (1959) reported that an increase in the amount of phosphoric acid accelerated

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tillering, but inhibited panicle growth.

Raghavan (1959) discussing the model agronomic experiments on sorghum found that at all centres the response to phosphoric acid was absent or low, except at Akola, where it was moderate with 2.3 maund (188.6 lb.) increase in yield of grain for 20 pounds of phosphoric acid.

Kapp (1935) stated that though the addition of $Ca(H_2Po_4)_2$ at the rate of 500 pounds per acre increased the phosphorus content of rice plants at 57 and 88 days of growth, did not affect the final yield of rice favourably.

According to Mahapatra and Sahu (1961) the response to phosphoric acid was lower than that of nitrogen applied at equal level. Three levels viz. 0, 20 and 40 pounds phosphoric per acre were tried and the optimum dose appeared to be 20 pounds, though the difference in yield due to levels of phosphoric acid was not significant.

Angladette et al. as quoted by Ignatieff and Page (1961) reported that in India where millets are most successfully grown in black soils, gave the greatest response to nitrogen but phosphorus had only very little effect. They also reported that on the whole, for millets a balanced nitrogen phosphorus fertilizer appeared to be most satisfactory. In the presence of adequate dose of nitrogen better response is generally reported for phosphoric acid. Persuing their

investigations on this basis in Bombay State, Pandya, Chavan and Shendge (1955) showed that there was considerable response to nitrogen and phosphoric acid at 40 pounds and 20 pounds respectively per acre, with a basal dose of 3 cart loads of farm yard manure for which treatment the highest yield was recorded in paddy crop.

MATERIALS AND METHODS

The investigation was carried out to study the comparative merits of the three common leguminous green manure crops of this State namely, Crotalaria juncea, Sesbania speciosa and Crotalaria striata in their response to different doses of P_2O_5 and their effect on the succeeding ragi crop.

1. Experimental site.

The experiment was carried out in the garden land, with red loam soils at the Agricultural College and Research Institute, Vellayani, from June 1963 to December 1963.

2. Treatments and layout.

(a) Treatments.

i. Whole plot treatments - Green manures.

G1 - Sesbania speciosa

G2 - Crotalaria juncea

G3 - Crotalaria striata

G4 - No legume

ii. Sub-plot treatments--different levels of P_2O_5

P0 - No P_2O_5

P1 - 20 lb. (9 Kg.) P_2O_5 per acre

P2 - 40 lb.(18 Kg.) P_2O_5 per acre

The following were the 12 combinations of treatments included in this trial.

Sesbania speciosa - G_1P_0, G_1P_1, G_1P_2.

Crotalaria juncea - G_2P_0, G_2P_1, G_2P_2.

Crotalaria striata - G_3P_0, G_3P_1, G_3P_2.

Control - G_4P_0, G_4P_1, G_4P_2.

(b) Layout.

The plots were laid out in split plot arrangement, in randomised block design with five replications. Plan of experimental layout is given in Fig.I.

(c) Size of plot.

Gross	- 21 x 21 ft.(6.40 x 6.40 metre)
Net	- 20 x 20 ft.(6.10 x 6.10 metre)
Total area	- 60 cents.

3. Materials.

(a) Seed rate:

i.Green manures.

Sesbania speciosa	- 15 Kg. per acre.
Crotalaria juncea	- 15 Kg. per acre.
Crotalaria striata	- 12 Kg. per acre.
ii.Ragi.	- 4 Kg. per acre.

The ragi strain selected for study was Co.7. This variety combines in itself the desirable characters like adaptability to wide range of soil types, climatic conditions and high fertility.

The seed material was obtained from Agricultural

College and Research Institute, Coimbatore.

(b) Fertilizers.

Phosphoric acid was applied in the form of superphosphate analysing 16 percent P_2O_5.

Potash was applied in the form of muriate of potash analysing 60 percent K_2O.

4. Cultivation.

(a) Sowing:

Green manure seeds were sown broadcast on 20th June 1963. The three legumes were assigned to main plots and manurial treatments to sub plots.

The ragi seeds were dibbled in rows with a spacing of 6 inches between rows on 19th September, 1963.

(b) Application of fertilizers:

No basal dressing was given. P_2O_5 was applied at three levels ie. 0 lb., 20 lb. (9 Kg.) and 40 lb. (18 Kg.) per acre, one level graded above and one below the dose recommended by the fertilizer work shop held in Madras (1960) for ragi. It was applied as a basal dressing before sowing the green manure seeds. In control plots phosphate was applied as a basal dressing before sowing ragi seeds.

The level of K_2O selected for study was a uniform dose of 40 lb. (18 Kg.) per acre, for all treatments based

on the above recommendations and was applied as a basal dressing before sowing ragi.

(c) Crop growth:

During the period of growth the meteorological conditions were normal and the general condition of the crops was satisfactory.

(d) Harvest:

The green manures were incorporated when the crop was 60 days old.

Ragi crop was harvested in two stages with an interval of ten days. First harvest commenced on 15th December 1963.

5. Characters studied:

1. Green manure plants.

(a) Height of plants:

Twenty standing plants were selected per plot at random and the height was recorded on the 60th day stage after sowing. All measurements were taken from the base of the plants to the highest terminal leaf bud.

(b) Number of nodules:

The number of nodules present on the root system of the sample plants was counted on the day of harvest. The plants were carefully lifted with the use of a spade to avoid mechanical dislodging of nodules and injury to the root system. The root system was washed free of soil

particles. The nodule count was taken and recorded.

(c) Green matter yield:

The sample plants in each plot were separately harvested and weighed. Afterwards the entire crop from each treatment was separately bundled and weight recorded.

(d) Dry matter content:

The sample plants were dried at 70°C. for 48 hours, followed by drying at 107°C. in air oven till consecutive weighings tallied. The weight of the material was recorded and the dry matter content per plot thus assessed.

ii. Ragi crop:

Twenty plants were selected from each plot at random, labelled and the following characters were studied.

(a) Height of plants:

The height of plants was taken on the 60th day stage after sowing. It was measured from the base of the plant to the tip of the panicle.

(b) Number of productive tillers.

Total number of productive tillers were taken from the sample plants on the 90th day after sowing.

(c) Number of fingers per ear head.

The number of fingers in the year heads of the sample plants were counted and recorded.

(d) Weight of grain:

The yield of grain from marked plants in each treatment, and the total yield from each treatment was recorded.

(e) Weight of straw:

The straw weight was also recorded treatment wise.

6. Chemical analysis:

A. Soil.

Before starting the experiment soil samples were collected and analysed for the following constituents.

(i) Total nitrogen: By Kjeldahl's method according to the procedure suggested by A.O.A.C.(1955).

(ii) Available phosphoric acid:-

By Dickman and Brays method as given by Jackson (1957).

(iii) Soil reaction: By glass electrode method.

Soil samples were again collected before the incorporation of legumes and analysed for total nitrogen according to the method cited above.

Finally a third set of soil samples were collected one month after the incorporation of green manures and analysed for total nitrogen and available P_2O_5.

B. Plant material.

(i) Green manure crop: From the air dried plant material from each treatment, representative samples were taken and nitrogen estimated by Kjeldahl's method, and expressed in percentage on dry matter basis.

(ii) Ragi.

The total nitrogen and total P_2O_5 in the grain and

straw determined separately, as per standard methods given Piper (1950).

7. Statistical analysis and interpretation.

The biological and chemical data were tested for significance as per 'Analysis of variance' described by Panse and Sukhatme (1957).

EXPERIMENTAL RESULTS

The observations made on the crops grown, and the data collected pertaining to this investigation, analysed statistically are presented in the Tables below:

TABLE I

Soil analysis values

Total nitrogen	- 0.065 per cent
Available phosphoric acid	- 0.00207 "
Soil pH	- 5.2

Analysis of variance tables for the characters studied were worked out and are furnished in the appendix (I-XV)

TABLE II

Mean height of green manure crops in centimeters at 60 days

	Sesbania speciosa (G_1)	Crotalaria juncea (G_2)	Crotalaria striata (G_3)	Mean
No P_2O_5 (P_0)	70.39	148.32	96.24	104.98
20 lb. P_2O_5 (P_1)	80.61	164.22	106.12	116.98
40 lb. P_2O_5 (P_2)	86.82	176.30	119.80	127.64
Mean	79.27	162.95	107.39	—

C.D. (at 5 per cent) for legumes: 3.60. G_2 G_3 G_1

C.D. (at 5 per cent) for levels of phosphorus: 1.17. P_2 P_1 P_0

C.D. (at 5 per cent) for levels of phosphorus in the whole plot: 3.096

C.D. (at 5 per cent) for combination of green manures and levels of phosphorus: 4.524

At 60 days stage Crotalaria juncea recorded the maximum height, followed by Crotalaria striata. Sesbania speciosa recorded the least height.

Application of phosphoric acid resulted in taller plants when compared to control plots. The difference in height at different levels of phosphoric acid was statistically significant.

TABLE III

Mean number of nodules per plant at 60 days

	Sesbania speciosa (G_1)	Crotalaria juncea (G_2)	Crotalaria striata (G_3)	Mean	Percentage increase over control
No P_2O_5 (P_0)	24.26	50.92	19.46	31.51	-
20 lb.P_2O_5 (P_1)	37.94	59.72	28.24	41.97	33.19
40 lb.P_2O_5 (P_2)	39.58	62.38	30.00	43.99	39.60
Mean	33.93	57.64	25.90		

C.D.(at 5 per cent) for legumes: 1.821 G_2 G_1 G_3

C.D.(at 5 per cent) for levels of phosphorus: 1.568 P_2 P_1 P_0

It is seen from the Table that the number of nodules produced by Crotalaria juncea was greater than that produced by Sesbania speciosa and Crotalaria striata.

The average number of nodules produced in plants, grown in plots receiving phosphate was significantly greater than no phosphorus control.

TABLE IV

Mean weight of green matter in Kilograms at 60 days

	Sesbania speciosa (G_1)	Crotalaria juncea (G_2)	Crotalaria striata (G_3)	Mean	Percentage increase over control
No P_2O_5 (P_0)	49.40	44.80	39.96	44.72	-
20 lb. P_2O_5 (P_1)	54.30	52.20	45.20	50.57	13.08
40 lb. P_2O_5 (P_2)	63.10	68.80	51.92	61.27	37.01
Mean	55.60	55.27	45.69	..	..
C.D. (at 5 per cent) for legumes:			4.470	$\overline{G_1\ G_2\ G_3}$	
C.D. (at 5 per cent) for levels of phosphorus			2.646	$P_2\ P_1\ P_0$	

The values in the Table indicated that the difference between yield of Sesbania speciosa and Crotalaria juncea was not statistically significant. But the green matter yield of these two legumes was superior to that of Crotalaria striata.

The yield obtained from plots treated with phosphate was higher than that from control plots. The difference in yield obtained from plots treated with different levels of phosphoric acid was statistically significant.

TABLE V

Mean weight of dry matter in Kilograms

	Sesbania speciosa (G_1)	Crotalaria juncea (G_2)	Crotalaria striata (G_3)	Mean
No P_2O_5 (P_0)	10.870	8.980	8.838	9.562
20 lb. P_2O_5 (P_1)	11.850	10.880	10.194	10.950
40 lb. P_2O_5 (P_2)	13.372	14.448	11.634	13.152
Mean	12.032	11.412	10.222	-
C.D.(at 3 per cent) for legumes:			1.097	$\overline{G_1\ G_2}\ G_3$
C.D.(at 5 per cent) for levels of phosphorus:			1.548	$P_2\ \overline{P_1\ P_0}$

The difference between the dry matter production of Sesbania speciosa and Crotalaria juncea was not statistically significant. However, they were superior to that of Crotalaria striata, and the difference was significant.

Application of phosphorus influenced the dry matter yield. The difference was statistically significant only at the highest level (40 lb. P_2O_5).

TABLE VI

Difference between available phosphoric acid in the soil in percentage, before starting the experiment and one month after incorporation of legumes

	Sesbania speciosa (G_1)	Crotalaria juncea (G_2)	Crotalaria striata (G_3)	Mean
No P_2O_5 (P_0)	0.00102	0.00111	0.00096	0.00103
20 lb. P_2O_5 (P_1)	0.00195	0.00163	0.00174	0.00177
40 lb. P_2O_5 (P_2)	0.00267	0.00279	0.00237	0.00261
Mean	0.00188	0.00184	0.00169	—

C.D. (At 5 per cent) for legumes: 0.000138 $\overline{G_1\ G_2\ G_3}$

C.D. (at 5 per cent) for levels of phosphorus: 0.00144 $\overline{P_2\ P_1\ P_0}$

The difference between the percentage of available phosphoric acid in the soil, incorporated with Sesbania speciosa and Crotalaria juncea was not significant but they were superior to Crotalaria striata.

Regarding the levels of phosphorus, maximum availability was recorded from the treatment P_2. Difference between treatments P_1 and P_0 was not statistically significant.

TABLE VII

Amount of nitrogen added by green manure crops in Kilograms per acre

	Sesbania speciosa (G_1)	Crotalaria juncea (G_2)	Crotalaria striata (G_3)	Mean	Percentage increase over control
No P_2O_5 (P_0)	27.652	24.532	20.144	24.110	-
20 lb. P_2O_5 (P_1)	30.130	28.800	23.440	27.457	10.4
40 lb. P_2O_5 (P_2)	34.440	37.612	26.884	32.978	36.7
Mean	30.740	30.316	23.489	..	..

C.D. (at 5 per cent) for legumes: 3.08 $\overline{G_1\ G_2}\ G_3$

C.D. (at 5 per cent) for levels of phosphorus: 1.34 $P_2\ P_1\ P_0$

Sesbania speciosa recorded the maximum amount of nitrogen added followed by Crotalaria juncea and Crotalaria striata. The difference between the first two treatments was not statistically significant. But they were superior to the third one.

Regarding the levels of phosphorus, maximum addition of nitrogen was recorded by the treatment P_2. Levels P_2 and P_1 were significant over control (P_0).

TABLE VIII

Difference in total nitrogen in percentage, in the soil before the experiment and after incorporation of legumes.

	Sesbania speciosa (G_1)	Crotalaria juncea (G_2)	Crotalaria striata (G_3)	Mean
No P_2O_5 (P_0)	0.00274	0.00278	0.00208	0.00253
20 lb. P_2O_5 (P_1)	0.00312	0.00298	0.00228	0.00275
40 lb. P_2O_5 (P_2)	0.00342	0.00344	0.00272	0.00319
Mean	0.00309	0.00318	0.00236	...
C.D. (at five per cent) for legumes			0.00078	$\overline{G_1\ G_2\ G_3}$
C.D. (at five per cent) for levels of phosphorus:			0.00021	$P_2\ P_1\ P_0$

There was no significant difference between the treatments Sesbania speciosa and Crotalaria juncea in enriching the soil. But both of them were superior to Crotalaria striata.

Regarding the levels of phosphorus, it was found that there was progressive increase in the percentage of nitrogen in the soil corresponding to levels. Maximum percentage was recorded by level P_2, and the level P_0 the minimum.

TABLE IX

Height of ragi in centimeters at ear-head emergence (60 days)

	Sesbania speciosa (G_1)	Crotalaria juncea (G_2)	Crotalaria striata (G_3)	No legume (G_4)	Mean
No P_2O_5 (P_0)	62.48	70.13	60.94	51.19	61.18
20 lb. P_2O_5 (P_1)	63.15	70.70	61.37	51.74	61.74
40 lb. P_2O_5 (P_2)	63.87	71.06	62.46	52.35	62.43
Mean	63.20	70.63	61.59	51.76	...

C.D. (at 5 per cent) for legumes (G) 1.39 $G_2\ G_1\ G_3\ G_4$

C.D. (at 5 per cent) for levels of phosphorus (P) 1.274 $\overline{P_2\ P_1\ P_0}$

C.D. (at 5 per cent) for levels of phosphorus in the whole plot: 1.823

C.D. (at 5 per cent) for combination of legumes and levels of phosphorus 2.270

The height of the crop was influenced by the different green manure treatments. Ragi grown in plots incorporated with G_2 recorded the maximum height and no green manure plot the least. Difference between different green manure treatments was statistically significant.

Regarding the levels of phosphorus, it was seen that, none of the treatments was effective in increasing the height of the crop.

Indirect application of phosphate through legumes influenced the height considerably. Maximum height was obtained from the application of 40 lb. P_2O_5 through G_2 and the minimum from treatment of no phosphate application through G_3.

TABLE X

Mean number of tillers (at the time of ear head emergence)

	Sesbania speciosa (G_1)	Crotalaria juncea (G_2)	Crotalaria striata (G_3)	No legume (G_4)	Mean	Percentage increase over control
No P_2O_5 (P_0)	5.06	5.26	4.58	3.70	4.65	..
20 lb. P_2O_5 (P_1)	5.28	5.66	4.94	3.94	4.96	6.5
40 lb. P_2O_5 (P_2)	6.04	6.62	5.84	3.38	5.72	23
Mean	5.46	5.85	5.12	4.01	-	-
Percentage increase over control	36.15	45.83	27.68	-	-	-

C.D. (at 5 per cent) for legumes	0.283	G_2 G_1 G_3 G_4
C.D. (at 5 per cent) for levels of phosphorus	0.122	P_2 P_1 P_0
C.D. (at 5 per cent) for levels of phosphorus in the whole plot	0.246	
C.D. (at 5 per cent) for combination of legumes and levels of phosphorus	0.377	

The treatment G_2 recorded the maximum number of tillers, followed by G_1, G_3 and G_4. The differences were significant statistically.

There was progressive increase in the mean number of tillers corresponding to levels of phosphorus. Levels P_2 and P_1 were statistically significant over P_0.

TABLE XI

Yield of grain in Kilograms per plot

	Sesbania speciosa (G_1)	Crotalaria juncea (G_2)	Crotalaria striata (G_3)	No legume	Mean	Percentage increase over control
No P_2O_5 (P_0)	2.511	3.054	2.347	1.675	2.396	—
20 lb. P_2O_5 (P_1)	3.366	3.691	3.336	1.789	3.045	27.08
40 lb. P_2O_5 (P_2)	4.164	4.513	3.836	2.240	3.683	53.7
Mean	3.347	3.753	3.173	1.901	—	—
Percentage increase over control	76.06	97.42	66.92	—	—	—

C.D. (at 5 per cent) for legumes	0.2529	G_2 $\overline{G_1\ G_3}$ G_4
C.D. (at 5 per cent) for levels of phosphorus	0.1508	P_2 P_1 P_0
C.D. (at 5 per cent) for levels of phosphorus in the whole plot	0.2955	
C.D. (at 5 per cent) for combination of legume and levels of phosphorus	0.2527	

The treatment G_2 recorded the maximum mean yield per plot. The difference between G_1 and G_3 was not statistically significant; but all the green manure treatments were statistically significant over no green manure control (G_4).

Progressive increase in the mean yield was noted for levels of phosphorus. Levels P_2 and P_1 were statistically significant over no phosphorus control (P_0)

TABLE XII

Yield of straw in Kilograms per plot

	Sesbania speciosa (G_1)	Crotalaria juncea (G_2)	Crotalaria striata (G_3)	No legume (G_4)	Mean
No P_2O_5 (P_0)	8.045	9.097	7.296	5.631	7.517
20 lb. P_2O_5 (P_1)	8.300	9.281	7.499	5.823	7.27
40 lb. P_2O_5 (P_2)	8.453	9.504	7.705	5.981	7.911
Mean	8.250	9.300	7.500	5.810	7.715
Percentage increase over control	41.98	60.07	29.08	---	---

C.D. (at 5 per cent) for legumes	0.405	$\underline{G_2\ G_1\ G_3\ G_4}$
C.D. (at 5 per cent) for levels of phosphorus	0.721	$\underline{P_2\ P_1\ P_0}$
C.D. (at 5 per cent) for combination of legume and levels of phosphorus	1.394	
C.D. (at 5 per cent) for levels of phosphorus in the whole plot	0.0815	

The treatment G_2 recorded maximum yield. All the treatments were statistically significant over control (G_4) and the difference between treatments was significant.

None of the phosphoric acid treatments was found to be significantly superior to control.

Application of P_2O_5 indirectly through legumes recorded significantly higher yields than direct application. Applying 40 lb. P_2O_5 through G_2 recorded maximum yield, 0 lb. P_2O_5 through the treatment G_3 the least.

TABLE XIII

Nitrogen content of Ragi grain in percentage

	Sesbania speciosa (G_1)	Crotalaria juncea (G_2)	Crotalaria striata (G_3)	No legume (G_4)	Means
No P_2O_5(P_0)	1.252	1.268	1.258	1.268	1.262
20 lb.P_2O_5(P_1)	1.272	1.290	1.286	1.266	1.279
40 lb.P_2O_5(P_2)	1.272	1.314	1.300	1.286	1.293
Mean	1.265	1.291	1.290	1.273	—

C.D. (at 5 per cent) for legumes 0.02767 $\overline{G_2\ G_3\ G_4\ G_1}$

C.D. (at 5 per cent) for levels of phosphorus 0.0839 $\overline{P_2\ P_0\ P_1}$

None of the treatments was found significantly superior in contributing to the nitrogen content of the grain.

TABLE XIV

Nitrogen content in Ragi straw in per centage.

	Sesbania speciosa (G_1)	Crotalaria juncea (G_2)	Crotalaria striata (G_3)	No legume (G_4)	Mean
No P_2O_5(P_0)	0.347	0.355	0.353	0.343	0.349
20 lb.P_2O_5(P_1)	0.356	0.356	0.358	0.348	0.354
40 lb.P_2O_5(P_2)	0.355	0.369	0.356	0.358	0.359
Mean	0.352	0.360	0.356	0.349	—

C.D. (at 5 per cent) for legumes (G) 0.0062

C.D. (at 5 per cent) for levels of phosphorus (P) 0.00839

None of the treatment was found significantly superior in contributing to the nitrogen content of the straw.

TABLE XV

Phosphorus content of the grain in percentage.

	Sesbania speciosa (G_1)	Crotalaria juncea (G_2)	Crotalaria striata (G_3)	No legumes (G_4)	Means
No P_2O_5 (P_0)	0.784	0.797	0.783	0.782	0.791
20 lb. P_2O_5 (P_1)	0.816	0.801	0.797	0.784	0.799
40 lb. P_2O_5 (P_2)	0.834	0.834	0.808	0.806	0.811
Mean	0.811	0.810	0.796	0.783	—

C.D. (at 5 per cent) for legumes: (G) 0.0295 $\overline{G_1\ G_2\ G_3\ G_4}$

C.D. (at 5 per cent) for levels of phosphorus (P) 0.0237 $\overline{P_2\ P_1\ P_0}$

Different green manure treatments and levels of phosphorus had no effect in increasing the phosphorus content of the grain significantly.

TABLE XVI

Phosphorus content of ragi straw in percentage

	Sesbania speciosa (G_1)	Crotalaria juncea (G_2)	Crotalaria striata (G_3)	No legume (G_4)	Means
No P_2O_5 (P_0)	0.2936	0.2944	0.2908	0.2868	0.2914
20 lb.P_2O_5 (P_1)	0.2962	0.2984	0.2958	0.2878	0.294
40 lb.P_2O_5 (P_2)	0.2974	0.3018	0.2994	0.2892	—
Mean	0.2953	0.2980	0.2953	0.2879	—

C.D. (at 5 per cent) for legumes (G) 0.6725 $\overline{G_2\ G_1\ G_3\ G_4}$

C.D. (at 5 per cent) for levels of phosphorus (P) 0.0089 $\overline{P_2\ P_1\ P_0}$

Percentage of phosphorus in the straw was not significantly influenced by the different green manure treatments and levels of phosphorus.

DISCUSSION

An investigation was carried out at the Agricultural College and Research Institute, Vellayani, to find out the effect of indirect application of phosphate through three common leguminous green manure crops of this state viz. Sesbania speciosa, Crotalaria juncea and Crotalaria striata on succeeding ragi crop, and to make a suitable recommendation based on the findings. Phosphate was applied at three levels, indirectly through the green manure crops mentioned above, and directly to the ragi crop. A uniform basal dose of potash was also given directly to the ragi crop.

The findings obtained in the investigation are discussed hereunder.

I. Height of legume:

From the observations recorded on height of legumes (Table II) it was found that, there was significant difference among the different treatments. Crotalaria juncea recorded the maximum height, followed by Crotalaria striata and Sesbania speciosa.

Since variation in height within the legumes is purely a function of the genetic make up under identical conditions of growth, the variation noted in the present study may be attributed to the inherent character of the legume concerned.

A comparison between the effect due to the application

of phosphoric acid at different levels indicated the following. Application of super phosphate at the rate of 20 lbs. (9 Kg.) and 40 lb. (18 Kg.) P_2O_5 per acre was found to have significant influence over control for the factor studied. This could be due to the effect of phosphoric acid in increasing the total leaf area, which consequently had pronounced effect on photosynthetic efficiency of the plant, as proved by the classical experiment at Rothamstead, reported by Russel (1961). Again this observation finds support from the findings of Hallowel (1943) and Stitt (1944) who observed that the vegetative growth of legumes increased considerably by the application of superphosphate.

II. Green matter production of legumes:

A study of the comparative green matter out put (Table IV) ranked the legumes in the following order of superiority. Sesbania speciosa > Crotalaria juncea > Crotalaria striata. The first two legumes were found to be significantly superior to the third, ie. Crotalaria striata. However the yield of green matter for the first two legumes did not differ significantly among themselves. Since green matter yield is mainly a function of vegetative growth, by virtue of inherent genetic make up of each individual legume, the superiority of the first two over the third can be explained as a natural phenomenon.

The results presented in the Table IV further

revealed that the green matter production was influenced by phosphate application. Super phosphate applied at the rate of 20 lb. (9 Kg.) and 40 lb. (18 Kg.) phosphoric acid per acre produced 13.08 per cent and 37.01 per cent respectively, more green matter than no phosphorus control. This indicates that with the higher levels of phosphoric acid there was corresponding increase in the green matter production. Sigh and Verma (1953) Varghese et al. (1957) and Sen and Bains (1962) also reported the same trend.

The importance of phosphoric acid in the nutrition of legumes has been established by earlier workers. The increase in green matter yield could be ascribed to the increase in the utilisation of nitrogen by the crop in presence of phosphoric acid as reported by Rao et al. (1957). The response of added phosphoric acid appears to be conspicuous, only under conditions of very low level of available phosphoric acid in the soil, as concluded by Parr and Bose (1948). In the present study also the positive response obtained in green matter production under phosphate treatment could be attributed to the poor status of available phosphoric acid of the soil as given in the Table I.

III. Dry matter content of legumes:

A study of the dry matter production of the different legumes (Table V) showed that the treatments Sesbania speciosa

and Crotalaria juncea were superior to Crotalaria striata. However there was no significant difference between the first two legumes.

It may be presumed that, under uniform conditions of growth, in which the investigation was carried out, the trend of dry matter production should be more or less similar to that of green matter output (Table IV). This variation may also be due to the variation in the maturity of the different legumes at the stage of harvest, viz. 60th day.

As regards the influence of phosphoric acid at different levels, on the dry matter production of legumes tried in this investigation, it was observed that (Table V) higher values for the factor studied were contributed by the application of 40 lb. (18 Kg.) of phosphoric acid per acre. At the same time, the application of phosphoric acid at the rate of 20 lb. (9 Kg.) per acre was not found to contribute materially, compared to the values of dry matter obtained from plots, where no phosphoric acid was applied. Both of them were found to be statistically on par.

Properties like increased cell division, fat and albumin formation and photo synthetic efficiency through an increased leaf area, could reasonably be presumed to be the cause for the higher rate of dry matter production. Similar observations had been reported by Bureau (1953) in his studies

on soybeans and also by Desai et al.(1957) on sannhemp.

IV. Nodule count:

Data as presented in Table III indicate that Crotalaria juncea produced the maximum number of nodules followed by Sesbania speciosa and Crotalaria striata.

In the study undertaken, the legumes included were classified as belonging to different genera and species. Legumes are found to differ widely in their inherent capacity to form nodules. Even the specific strain of inoculam responsible for nodulation in a particular genera or species, vary in their capacity to produce effective nodules among its different members.

From the results shown in the Table III, it was seen that application of phosphoric acid at the rate of 40 lb. per acre (18 Kg.) was significantly superior in nodule formation to 20 lb. (9 Kg.) P_2O_5 per acre. Both the levels tried were found to be significantly superior to no phosphorus control.

Application of super phosphate to the soil has the effect of stimulating the microbial population; as reported by Whyte et al. (1953) and Sen and Bains (1955). Phosphoric acid induces the formation of greater number of root lets and root hairs in plants. (Russel,1961). The infection of rhizobium for the formation of nodule, mainly takes place

through the root hairs, as reported by Nutman (1958). This explains the reason for the formation of greater number of nodules in plants grown in plots applied with phosphate. The result obtained in the present investigation was in association with the finding reported by Nair et al. (1957).

V. Soil nitrogen:

From the study of the data presented in the Table VIII it was found that Sesbania speciosa was the most effective green manure in enriching the soil with nitrogen, followed by Crotalaria juncea and Crotalaria striata. However there was no significant difference between the first two.

The quantity of nitrogen added by legumes, depends on many factors viz. the kind of legume, the condition of growth, stage of ploughing in and soforth. (Virchandari and Khan, 1953). The legumes tried in this study were of different types. Their growth habit, nodule production and green matter production varied considerably as discussed earlier. So the difference in the total nitrogen in the soil before starting the experiment and after incorporation may reasonably be attributed to the factors mentioned above.

From the data presented in the table cited above, it was seen that the application of phosphate to legumes significantly influenced in increasing the nitrogen status of the soil. According to Sen and Rao (1953) the nodule

bacteria require an adequate supply of phosphorus for their normal development and nitrogen fixation in symbiosis with the legume. So the increase in the amount of nitrogen fixed at higher levels of phosphorus can be reasonably attributed to this phenomenon. This observation was in line with the findings reported by Sen and Bains (1955 and 1957) Varghese et al.(1957) Panse (1959) and Patel, Ghose and Sen (1963) who found that the amount of nitrogen added to the soil by legumes increased considerably at higher phosphate levels. Thus the result in the present investigation indicates that with higher levels of P_2O_5 applied, nitrogen in the soil also increased.

VI. Available phosphate in the soil:

From the figures presented in the table VI it was seen that the availability of phosphoric acid in the soil increased considerably by application of phosphate through the legumes. Sesbania speciosa and Crotalaria junoea increased the available phosphoric acid status in the soil, more than Crotalaria striata. But the difference between the first two was not significant.

Moser (1942) showed that the availability of phosphoric acid increased due to the decomposition of green manures. In the present study also the variation in the ability among the different legumes tried in increasing the availability of phosphoric acid can be attributed to the difference in the green

matter production by them (Table IV) and also to their capacity to get decomposed in the soil.

There was a progressive increase in the availability of phosphoric acid corresponding to levels. Differences between treatments P_2 and P_1; and P_1 and P_0 were not significant. But there was significant difference between the treatments P_2 and P_0. Thus the results obtained in this investigation indicated increase in phosphate availability with indirect application through legumes. This is in conformity with the observations made by Govindarajan (1951) Sen and Bains (1955 and 1957) and Patel, Ghosh and Sen (1963).

The increased availability of phosphate as reported by Sen and Bains (1955) may be due to the production of large quantities of carbon di oxide during the decomposition of organic matter, leading to the lowering of the pH of the soil solution and also due to the conversion under the influence of decomposing organic matter, to organic phosphates which are better available. Struthers and Siebing (1950) favour the latter view and showed that, the organic acids produced by bacterial decomposition of organic manures form compounds and complexes with phosphate inhibitors such as iron and aluminium in the soil and there by release phosphate for the benefit of crop growth. Considering the fact that the soil under investigation was laterite, with pH 5.2 this view appears to be more reasonable. Varghese *et al.*(1957) obtained the same trend under similar soil and climatic conditions.

RESIDUAL EFFECT ON SUCCEEDING RAGI CROP

1. Height of ragi:

From the data presented in the Table IX it was found that maximum height was recorded by the crop grown in plots incorporated with Crotalaria juncea. In order of superiority, the legumes were placed in the following order. Crotalaria juncea > Sesbania speciosa > Crotalaria striata. The differences noted among them were statistically significant.

Since height of the plant is a vegetative character and nitrogen has significant influence on vegetative growth, it could be presumed that the added nitrogen, through the incorporation of legumes, had contributed to the increase in height. Grist (1955) and Ghosh et al. (1960) recorded similar observations in paddy at higher levels of nitrogen.

From the data presented in the tables for values of nitrogen added (Table VII) soil analysis figure for total nitrogen after incorporation of legume (Table VIII), green and dry matter production of legume (Tables IV and V) it was found that the treatments Crotalaria juncea (G_2) and Sesbania speciosa(G_1) were on par, but superior to Crotalaria striata (G_3).

Since G_1 and G_2 were statistically on par, it is reasonable to persume that the increase in height of the crop, grown in plots treated with G_2, may be due to the increased availability of nitrogen from that treatment.

There was no significant variation in the height of

the plant at different levels of phosphoric acid tried.

II. Number of tillers:

From the observations recorded on this factor (Table X) it was found that, ragi grown in plots treated with legumes recorded significantly higher number of tillers than no green manure control. Crotalaria juncea (G_2) Sesbania speciosa (G_1) and Crotalaria striata (G_3) recorded 45.83, 36.18 and 27.68 per cent more number of tillers, respectively than control (G_4). Tiller production, being a vegetative character is influenced by nitrogen, as reported by Narasimha murthy (1960). Nitrogen applied to the plots through the green matter added, by the treatments G_2 and G_1 were on par and were significantly higher than G_3 as shown in the Table VII. So the difference in the number of tillers from the different green manure treatments could be ascribed to the variation in the amount of nitrogen added through them. This trend again, is in agreement with the findings of Relwani and Ganguly (1959) in paddy.

Application of phosphoric acid increased the tiller production in ragi. At 40 lb. (18 Kg.) level the number of tillers formed was significantly higher than that of 20 lb. (9 Kg.) level which again was superior to no phosphorus level. Similar response was reported by Takijima, Shiojima and Konno (1959) and Venkiteswaran (1956) in paddy. In the present study indirect application of phosphoric acid through legumes influenced tiller production considerably.

Among the combinations, application of 40 lb.(18 Kg.) phosphoric acid through Crotalaria juncea recorded the maximum number of tillers. The minimum number was for no phosphoric acid with Crotalaria striata. Tillering, being a vegetative character, was influenced by the availability of nitrogen. From the table VII it could be seen that the amount of nitrogen added through the treatment Crotalaria juncea at 40 lb.(18 Kg.) level was the highest. Sircar and Sen (1941) growing paddy at three levels of phosphorus found that the greatest intake of nitrogen was associated with the highest phosphorus level. So the increased number of tillers from plots receiving higher level of P_2O_5 through legume may be attributed to the increased amount of nitrogen absorbed by the crop.

III. Grain yield:

A study of the comparative effect of various treatments on grain yield (Table XI) indicated that higher yields had been obtained from plots treated with green manure crops. Maximum yield was obtained from the treatment Crotalaria juncea (G_2). It was followed by Sesbania speciosa (G_1) and Crotalaria striata (G_3) and the difference between them was not significant. But all the green manure treatments gave significantly higher yield than no green manure control.(G_4). The treatments G_2, G_1 and G_3 produced 97.42, 76.06, and 66.92 per cent higher yield respectively over G_4. The variation in the production of grain by the different green manure treatments could be due to the variation in the effective tiller

production, as influenced by the difference in the amount of nitrogen added through them (Table VII). Several experiments conducted on ragi have conclusively proved that the crop responded well to nitrogen. Sanyasiraju (1952) recorded response in ragi crop for nitrogen. Narasimhamurthy (1952) reported progressive increase in yield of ragi for nitrogen levels upto 50 lb. per acre.

As for the different levels of phosphoric acid tried, on the yield of ragi (Table XI) it was found that the level P_2 recorded the maximum grain yield followed by P_1 and P_0. All the treatments were significant among themselves. The treatments P_2 and P_1 produced 53.7 and 27.08 per cent more grain yield respectively over control (P_0). Chin (1952) reported that the response to phosphate was significant in red soils low in available P_2O_5. From the table I it could be seen that the available P_2O_5 status in the soil, where the investigation was carried out, was very low and hence the significance due to added phosphate. Again the results obtained in the present study was in conformity with the findings of Bains (1949) who reported significantly higher yields in wheat, at higher levels of P_2O_5.

The table cited above further reveals that indirect application of phosphate through green manures increased the grain yield of ragi. Among the combinations, application of 40 lb. (18 Kg.) of P_2O_5 through the treatment G_2 produced the maximum yield followed by G_1 and G_3. Minimum production was

from the combination of P_0 and G_3. This finding is in agreement with the results reported by Venkatarao and Govindarajan (1960) who recorded higher grain yield in ragi by the application of phosphate in conjunction with leguminous green manure crops. In the present study also the availability of phosphoric acid increased due to the indirect application through legumes (Table VI) and hence the increase in grain yield may be attributed to this reason. Singh (1961), Rao et al. (1962) have also reported the same trend.

IV. Straw yield:

In the study on the straw yield of ragi (Table XII) it was observed that the crop treated with Crotalaria juncea(G_2) recorded the maximum, followed by Sesbania speciosa (G_1) and Crotalaria striata. Control plot (G_4) recorded the lowest yield. Percentage increase for different treatments G_2, G_1 and G_3 was found to be 60.07, 41.98 and 29.08 respectively over control (G_4). The increase in the yield of straw may be ascribed to the increased tiller production. (Table X).

This finding is in line with the observations made by Venkata Rao and Govindarajan (1960) who reported higher straw yield in ragi due to green manuring with legumes. Same results had been reported by Venkitasubramaniyan and Dorairaj (1952).

Regarding the levels of phosphorus, no significant difference was obtained between the different treatments.

This result is in line with the finding reported by Nair (1963) in ragi.

Indirect application of phosphate through legumes produced higher straw yield than direct application. Among the combinations 40 lb. (18 Kg.) P_2O_5 with G_2 recorded the maximum output. The difference in the straw yield in different green manure treatments could be due to the variation in the amount of nitrogen made available by them. Sircar and Sen (1941) reported that in paddy increased up take of nitrogen was associated with higher levels of phosphoric acid. In the present investigation also the influence of phosphoric acid applied indirectly through green manures, on straw yield of ragi, could be due to the increased uptake of nitrogen at high levels of P_2O_5.

V. Chemical analysis of grain and straw:

(a) Nitrogen.

Chemical analysis of the grain and straw (Table XIII and XIV) showed that none of the treatment was significantly superior in increasing the nitrogen content. The different green manure treatments and levels of phosphoric acid tried showed considerable variation in yield, (Tables X and XI) but the nitrogen content was not affected. This finding is in line with the observation made by early investigators like Sturgis (1952) Panos (1959) and Sethi, (1959) who reported that the yield of cereals increased at high nitrogen levels,

but the percentage of the element in the grain and straw was not affected significantly.

(b) Phosphorus:

This factor also was not significantly influenced by any of the treatments (Table XV and XVI). From the tables cited above, it was seen that, there was a general trend of increase in the percentage of this element in the grain and straw at increasing levels of phosphorus though not statistically significant. Nair (1963) observed that, the different levels of phosphoric acid applied to ragi, did not affect significantly the phosphorus content in the grain and straw.

SUMMARY AND CONCLUSIONS

An investigation was carried out to study the response of three common leguminous green manure crops of this State viz. Sesbania speciosa, Crotalaria juncea and Crotalaria striata to different doses of P_2O_5 and their comparative residual effect on the succeeding ragi crop. The experiment was laid out in the Farm, attached to the Agricultural College and Research Institute, Vellayani. Phosphate was applied at three levels viz. 0, 20 and 40 lb. per acre. This was applied directly to the ragi crop, and also indirectly through the preceeding green manure crops. A uniform basal dose of potash (40 lb. K_2O per acre) was applied directly to ragi in all the treatments.

The following plant characters were studied, for the green manures and ragi crop.

Green manure crop.

i. Mean height of plants in centimeters on 60th day after sowing.

ii. Mean number of nodules per plant.

iii. Weight of green matter.

iv. Weight of dry matter.

v. Amount of nitrogen added through legumes.

Ragi crop.

i. Height in centimeters at earhead emergence

ii. Mean number of tillers

iii. Yield of grain

iv. Yield of straw

v. Nitrogen content of grain and straw.

vi. Phosphorus content of grain and straw.

The total nitrogen and available phosphoric acid in the soil were determined before commencement of the experiment and one month after incorporation of the legumes.

The conclusions are summarised below:

1. (a) Crotalaria juncea recorded the maximum height at 60 days followed by Crotalaria striata and Sesbania speciosa.

(b) Application of phosphate resulted in taller plants. Plant height showed significant difference between the various levels of phosphorus tried.

2. (a) Crotalaria juncea recorded the maximum number of nodules while Crotalaria striata recorded the least.

(b) There was a progressive increase in the number of nodules formed with increasing levels of phosphate.

3. (a) The difference in green matter production between Sesbania speciosa and Crotalaria juncea was not significant. However they were better than Crotalaria striata in green matter production.

(b) Phosphate treatments increase the green matter production of the legumes.

4. (a) Sesbania speciosa and Crotalaria juncea were

significantly better than Crotalaria striata in dry matter production, with no significant difference between themselves.

(b) Phosphate applications influenced the dry matter production significantly, but only at the 40 lb. level.

5. (a) The amounts of nitrogen added to the soil by Sesbania speciosa and Crotalaria juncea in the form of green matter were greater than that added through Crotalaria striata.

(b) Application of graded doses of phosphorus to the green manure crops increased in a graded manner the total amount of nitrogen, added through them.

6. In enriching the soil nitrogen, ploughing in of Sesbania speciosa and Crotalaria juncea was found to be better than Crotalaria striata.

7. Incorporating Crotalaria juncea and Sesbania speciosa in soil considerably increased the available phosphoric acid in the soil while Crotalaria striata could not do so to such a marked extent.

Ragi.

1. (a) Height of ragi was significantly influenced by the different green manure treatments.

(b) Different levels of phosphorus were found to have no effect on the height of plants.

2. (a) Production of tillers was found to be highest in

plots incorporated with Crotalaria juncea, followed by Sesbania speciosa and Crotalaria striata.

(b) There was progressive increase in the number of tillers corresponding to levels of phosphorus.

3. Ragi crop, grown in plots incorporated with Crotalaria juncea recorded the maximum yield of 375.3 kilograms of grain and 930.0 kilograms of straw per acre.

Application of 40 pounds of P_2O_5 per acre recorded a maximum yield of 368.3 kilograms per acre of grain only.

Applying 40 lbs. of P_2O_5 per acre to Crotalaria juncea and subsequently raising a ragi crop in the plot was found to produce 451.3 kilograms of grain and 950.4 kilograms of straw per acre.

4. Chemical analysis of the grain and straw brought out that the nitrogen and phosphorus content was not influenced by any of the treatments.

From the results of the present investigation, it may be concluded that the application of P_2O_5 at 40 lb. per acre to Crotalaria juncea, produced maximum grain and straw yield in the subsequent ragi crop under the soil and climatic conditions of Vellayani.

LITERATURE CITED

LITERATURE CITED

Acharya, C.N., J.Jha and S.P.Jain.	1953	Studies on the building up of soil fertility by phosphate fertilization of legume. J.Indian Soc.Soil Sci.1: 83-92.
Anant Rao, N.K., J.P. Agarwal, K.S.Pawar and N.R. Yadav.	1957	Phosphate manuring of sannhemp as green manure. Indian J.Agron. 1: 215-219.
Anonymous.	1957	Annual report of the Division of Agronomy, I.A.R.I. (Summary of main results for the year 1956-57)
Anonymous.	1962	Third report of Model Agronomic Experiments. I.C.A.R. Publication. New Delhi.
Anonymous.	1963	Fifth report of Model Agronomic Experiments. I.C.A.R. Publication. New Delhi.
A.O.A.C.	1955	Official methods of analysis. Washington.
Ballal, D.K. and N.P. Natu	1961	Fertilization of legumes. I.C.A.R. Proc. Series 208.218.
Blaser, R.E., Volk, G.M and F.B.Smith	1947	The yield, composition and nodulation of several clover varieties as affected by sources of calcium and phosphorus in combination with varieties. Soil Sci.Soc.Amer.Proc.6: 298-302.
Brenes, E.J., R.Millar and W.R.Sc Hnehl	1955	Fertilizer values of Rhenania type phosphate in green house experiments. Agron.J. 47: 77-82.
Buckman, H.O and N.C.Brady	1961	Nature and Properties of Soils. Macmillan Company Ltd., Galt, Ontario.
*Celino, M.S.	1950	Influence of phosphorus on nodulation and growth of legumes. J.Soil Sci.Soc.Philippines 2: 229-37.

Chandanani, J.J. and S.S. Oberoi	1956	Studies on the value of various legumes as a source of green manure. Indian J.Agron. 1: 95-103.
Chin, D.T.	1958	A study on the response to phosphate fertilizers in paddy soils. J.Agric.Chem.Taiwan 7: 34-35
*Collison, R.C.	1933	Mineral and Water Relations and Final Nitrogen Balance in Legume and Non legume crop rotations for a period of 16 years. N.Y.State Agr.Exp.Sta.Bull: 212.
Collings, G.H.	1954	Commercial fertilizers, their sources and use. Mc Graw Hill Book Company Inc. New York.
Cook, R.L., and C.E.Millar	1944	Fertilizers for legumes. Mich.St.Coll.Agrl.Expt.Sta. Spec.Bull. No.328.
Crofts, F.C.	1954	Super phosphate and molybdenum response in peas. Agriculture Gaz. N.S.W. 65:185-194
Desai, A.D., T.Seshagiri Rao and V.Seetharama Rao.	1957	Phosphate manuring of green manure crop. J.Indian Soc.Soil Sci. 5: 219-225.
De Turk, E.E.	1942	The problem of phosphatic fertilizers. Univ.Illinois. A.E.S.Bull.No.484.
Dutta, S.K and K.N.Sharma	1961	Phosphate manuring of Green crop for Tea plantations. Indian J.Agron.5 (3): 200-205.
*Eichinger, A.	1913	Legume cultivation and inoculation. Expts.Pflanzer, 1912, Abst. in Exot.Sta.Rec. 27.
*Ekeleen, L.L. and C.P. Beyers.	1958	The influence of phosphate fertilizers on growth and nutrient uptake of blue-bitter lupin. S.Afr.Agric.Sci.1: 25-45

Fellers, C.R.	1918	The effect of inoculation, fertilizer treatment and certain minerals on the yield, composition and nodule formation of soybeans. Soil Sci. 6: 81-89.
*Fisher, R.K., K.Sammet and H.Pochenrieder.	1950	Relation between nutrient uptake, nodule formation and activity of nodule bacteria in soybeans under the influence of varying fertilizers. Bodrik. U.Pflanzeneriber 27: 181-197.
Franklin, L., C.G.Davis and C.A. Brewar.	1940	Louisiana Ag.Exp.Sta.Bull.318.
Govindarajan, S.V. and B.V.Venkata Rao.	1952	Manures and fertilizers; Their effecient and effective use for increased crop production. J.Mysore Agric.Exp.28(4): 77-91.
Granes, D.L., F.G.Viets and S.H.Shih.	1958	Proportionate uptake of soil and phosphorus by plants as affected by nitrogenous fertilization II. Field experiments with sugar beet and potatoes. Soil Sci.Soc.Proc.
Howell, R.W.	1954	Phosphorus nutrition of soybeans. Plant Physiol., 29 (5) 477-83.
Hutchings, T.B.	1936	Relation of phosphorus to growth, nodulation and composition of soybeans. Missouri. A.E.S.Res.Bull.243.
Ignatieff Vladimir and Harold J.Page.	1960	Editors, Efficient use of fertilizers. F.A.O. Rome, Italy.
Jackson, M.L.	1958	Soil Chemical Analysis Published by Prenticie-Hall Inc.N.J.
James, L., L.Roberts and Frank R.Olson.	1944	Influence of phosphorus and potassium on symbiotic nitrogen fixation. J.Amer.Soc.Agron.36: 637-647.

Kanwar, J.S.	1962	Direct and residual effect of major and micronutrients applied to berseem in sandy loam soil. Indian J.Agron. 7: 112-118.
Kapp, L.C.	1935	Phosphate fertilization for rice under submerged conditions. Proc.Assoc.S.Agric.Workers 34th, 35th, 36th Ann.Con 1933-35 73-74.
Karunakar, P.D.	1948	I.C.A.R. Proceed.7th Meet. Crops and Soil Wing. Board. Agric. & Ani.Husb.in India. Manager of Publ.Delhi, 1950. 161.
Khan, A.R.	1952	Miracle clover Sci. & Cult., 18 (3): 153-157.
Khan, A.R., M.R. Bajpai and B.P.Mathur.	1954	Response of berseem to fertilizers and comparison of after effects with those in cereals. Indian J.agric.Sci.24: 317-325.
Khan, A.R and B.P.Mathur.	1957	Effect of burying sannhemp as green manure on the yield of wheat. Indian J.agric.Sci.27: 171-176.
Krishna Rao, D.V.and G.Raja Rao.	1962	Phosphate manuring of legumes and its residual effects on paddy. Andhra agric.J.9 (1): 21-25.
Krishna Rao, D.V.and T.Seshagiri Rao.	1962	Phosphate manuring of legumes and its residual effects. Andhra agric.J. 9: 21-25.
*Ludecke, H.	1941	The Importance of phosphoric acid for growth of soybeans and for activity of their nodule bacteria. Abst.Soils & Fert. 1942, 73.
Lyon, T.L. and J.A.Bizzell.	1934	A comparison of several legumes with respect to nitrogen accretion. Jour.Amer.Soc.Agron.26: 651-56.
Mac Taggart.	1921	The effect of fertilizer salts on the growth and nitrogen content of peas and alfalfa. Soil Sci.11: 435-455.
Mhapatra, I.C. and B.N.Sahu.	1961	Phosphate needs of rice crop. Indian J.Agron.5: 219-224.

Mercer, A.D.	1948	Improving soil fertility by indirect nitrogenous manuring. Ag.Jour.Figi. 19: Nos. 3 & 4.
Mirchandani, T.J. and A.R.Khan.	1953	Green manuring. I.C.A.R. Rev.Series (6): 35 New Delhi.
Mukerji, B.H. and Aggarwal.	1950	I.C.A.R. Bull. 68.
Nair, K.R.	1963	Response of CO.7 Ragi (Elusine coracana) to phosphate and potash. Dissertation submitted for M.Sc.(Ag.) degree of the University of Madras. 1963.
Nair, K.S., S.Varadarajan and T.R.Iyengar.	1957	Preliminary studies on raising of Sesbania speciosa for green manure on laterite soils. Madras agric.J. 44: 447-456.
*Nutman, P.S.	1958	The physiology of nodule formation. Nutrition of the legumes. Proc.Univ.Nottingham fifth Easter Sch.Agric.Sci. 87-107.
Okada, T.	1931	Influence of fertilizer to the absorption of nitrogen. Tram: Tottori. Soc.Agric.Sci.4: 67-70.
Pandya, P.S., V.M.Chavan and P.V.Shendge.	1955	A brief review of research work on small millets in Bombay State. Poona agric.Coll.Mag. 46 (2 & 3) 142-147.
Panikkar, M.P.	1958	Co-ordination of Agricultural Research in India. Agronomy I.C.A.R. New Delhi.
Panos, D.A.	1959	The growth of legumes in conjunction with phosphate fertilizer as a means of increasing and stabilising soil fertility and agricultural productivity in Greece. Empire J.Exptal.Agric.27 (106): 98-1 Abstr.Indian J.Agron. 2 (2): 63.

Panse, V.G. and P.V. Sukhratme.	1961	Statistical methods for agricultural workers. I.C.A.R. New Delhi.
Parr, C.H. and R.D.Bose.	1945	Phosphate manuring of legumes II. Indian Fmg. 5: 201-208.
Parr, C.H. and R.D.Bose.	1947	Phosphate manuring of legumes for increased food and fodder. Indian Fmg. 8: 267-276.
Parr, C.A. and S.Sen.	1948	Phosphate manuring of legumes in relation to green manuring. Indian Fmg.9: 227-238.
Patel, S.P., A.B.Ghose and S.Sen.	1963	Effect of phosphate manuring of berseem on the fertility status in Delhi soils. J.Indian Soc.Soil Sci.2: (2) Q25-258
Piper, C.S.	1950	Soil and Plant Analysis. The University of Adelaide, Adelaide.
*Prucha, M.J.	1915	Physiological studies of Bacillus radicicola of Canada field beans. N.Y. (Cornell) Agr. Col.Mem.5:1-83.
Raghavan, D.	1959	Fifth report Model Agronomic Experiments I.C.A.R. Publication. New Delhi.
Raheja, P.C.	1960	Crop response to phosphatic fertilizers. Fertil.News 5: 3-8
Ramiah, K.	1952	Manuring of rice in India. I.C.A.R.Bulletin No.38.
Rao, D.G.R.	1923	Manuring of green manure crops. Ann.Rep.Mysore Dept.Agri.99:104.
Rao, A.N.K., R.Singh and P.S.Verma	1954	Increasing levels of phosphate on berseem and the residual effect on wheat.Allahabad Fmr.28: 66-70.

Raychowdary, S.P. and B.V.Subbiah.	1952	Phosphate manuring of legume and its role in building up the fertility of Indian soils. Trans.int.Soc.Soil Sci.Comm.II & IV 2: 253-258 Soils & Ferti.17: (2), 794.
Relwani, L.L. and B.D.Ganguly.	1959	Effect of green manuring in conjunction with fertilizers on paddy yields. Indian J.Agron.28: 1-13.
Robinson, R.R.	1944	The response of various forage grasses and legume seedlings to phosphate fertilization under green house conditions. Soil Sci.Soc.Amer.Proc.9: 1947-50.
*Sammet, K.	1942	The importance of phosphoric acid for leguminous crops with special reference to soybeans. C.A. 38 (3406): Abst.Soils & Fert(8) 1944: 232.
Sen, S.	1963	Soil fertility and fertilizer use. Abst.Agricultural Research. 3(1):1
Sen, S. and S.S.Bains.	1951	Indian J.agric.Sci. 21: 197-202.
Sen, S. and S.S.Bains.	1955	Effect of farm yard manure and super phosphate on berseem yield, nodulation and nitrogen fixation. Indian Soc.Soil Sci. 3: 41-49.
Sen, S. and S.S.Bains.	1956	Phosphate manuring of legumes. Effect on yield and quality of cow peas and after effects on wheat. J.Indian Soc.Soil Sci.4 (4): 284.
Sen, S., S.S. Bains and B.P. Mathur.	1962	Phosphate manuring of legumes. J.Indian Soc.Soil Sci. 10: 283.
Sen, S. and W.V.B.S.Rao.	1953.	Phosphate fertilization of legumes. I.C.A.R. Rev.Series. 3: 32. New Delhi.
Sethi, R.L.	1959	Manuring of paddy. Imp.Coun. Agric.Res.Misc.Bull.38

Sikka, S.M. and V.B.L.Jain.	1958	Manuring of guar (Cyamopsis tetragonoloba) with phosphate and micronutrients and its effect on the physical and chemical properties of soil. Indian J.Agron.3: 89-97.
Singh, G. and P.S.Verma.	1953	The effect of phosphate fertilising of berseem on its yield and quality. Agr.Univ.J.Res.2: 45-51.
Sircar, S.M. and J.N.Sen.	1941	Physiology of rice--Effect of phosphorus deficiency on growth and nitrogen metabolism in rice leaves. Indian J.agric.Sci.11: 193-204.
Smith, C.A.N.	1944	Super phosphate and basic super phosphate in the establishment of subterranean clover on a lateritic sandy loam soil. Journ.Dept.Ag.South Aust. 47: 299-302.
Stewart, A.B.	1947	Report on soil fertility investigations in India with special reference to manuring. Army Press, New Delhi.
Stitt, R.E.	1944	Effect of fertilizers on standard yield of crimson clover. Jour.Amer.Soc.Agron.36 (5): 464-467.
Sturgis	1952	Protein in rice as influenced by variety and fertilizer levels. La.State.Univ.Bull.466: 28.
Swell, M.C. and F.L.Gainey.	1930	Interaction of nutrients and soil reaction on growth and inoculation of alfalfa. Soil Sci.30: 89-97.
Takijima, Y., M.Shiojima and K.Konno.	1959	Studies on soils of peaty paddy fields. vii.Change of soil productivity with special reference to the effect of applying phosphatic fertilizer. J.Sci.Soil Tokyo. 30: 457-478.
Truesdell, H.W.	1917	The effect of phosphorus on alfalfa bacteria. Soil Sci.3: 77-98.

Udai Bhan Singh.	1961	After effects of green manure crops on uptake of nitrogen and phosphorus by wheat. Indian J.Agron.6(2):98-104.
Varghese, E.J., P.L.Ramanandan and P.K.Thomas.	1957	A note on phosphate manuring of Crotalaria striata. Indian Coconut Journal 10: 29-32.
Venkata Rao, B.V. and S.V.Govindarajan.	1960	Influence of green manures on phosphate c utilisation by crops. J.Indien Soc.Soil Sci.8(3):145.
Venkata Rao, B.V. and K. Shankar	1960	Influence of soil phosphorus status on the composition of sannhemp. J.Indian Soc.Soil Sci.8:129-132.
Vyas, N.D.	1953	Effect of some indigenous phosphate on nitrogen fixation through peas. J.Indian Soc.Soil Sci.1: 41-46.
Vyas, N.D. and J.R.Desai	1953	Effect of different doses of super phosphate on fixation of atmospheric nitrogen through pea. J.Indian Soc.Soil Sci.1: 33-40.
*Wholtman and Bergene	1902	The relation of nitrogen to nodule development and fixation of nitrogen by certain legumes. N.J.Agrl.Exp.Stn.Bull.No.436.
Wilson, J.K.	1917	Physiological studies of B.radicicola and factors influencing nodule formation. N.Y.(Cornell) Agr.Exp.Sta.Bull.386.
*Wing, J.E.	1913	Phosphorus for alfalfa fields. Bruders Gaz.64: 89.

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* Original not seen.

APPENDICES

APPENDIX I

Height of green manure crops in 60 days--Analysis of variance

Source	S.S.	D.F.	Variance	'F'
Block	21.14	4	5.285	0.29
Legumes	54384.71	2	27192.35	1504 *
Error 1	144.69	8	18.08	—
Phosphorus	3878.19	2	1939.09	340.78 *
Interaction	212.01	4	53	9.31 *
Error	136.71	24	5.69	

* Significant at 5 per cent level.

APPENDIX II

Number of nodules--Analysis of variance

Source	S.S.	D.F.	Variance	'F'
Block	100.10	4	25.03	5.35 *
Legumes	8170.88	2	4085.44	872.96 *
Error 1	37.42	8	4.68	---
Phosphorus	1344.68	2	672.34	149.74 *
Interaction	48.21	4	12.05	2.68
Error 2	107.88	24	4.49	---

* Significant at five per cent level

APPENDIX III

Weight of green matter--Analysis of variance.

Source.	S.S.	D.F.	Variance.	'F'
Block	124.87	4	31.22	1.10
Legumes	949.51	2	474.76	16.75 *
Error 1	226.80	8	28.35	---
Phosphorus	2114.14	2	1057.07	85.66 *
Interaction	237.72	4	59.43	4.82
Error 2	296.13	24	12.34	---

* Significant at five per cent level.

APPENDIX IV

Weight of dry matter--Analysis of variance

Source.	S.S.	D.F.	Variance	'F'
Block	4.812	4	1.203	0.703
Legume	25.383	2	12.691	7.73 *
Error 1	13.653	8	1.706	---
Phosphorus	98.318	2	49.159	116.20 *
Interaction	14.665	4	3.666	8.66 *
Error 2	10.161	24	0.423	---

* Significant at five per cent level.

APPENDIX V

Difference in available P_2O_5 in the soil - Analysis of variance

Source.	S.S.	D.F.	Variance	'F'
Block	0.0000003508	4	0.0000000877	3.6
Legumes	0.0000003063	2	0.0000001532	6.2 *
Error 1	0.0000001953	8	0.00000002441	-
Phosphorus	0.000018807	2	0.000009403	2.619
Interaction	0.0000004989	4	0.0000001247	0.035
Error 2	0.00008615	24	0.00000359	-

* Significant at five per cent level.

APPENDIX VI

Amount of nitrogen added by green manure crops in Kilograms per acre - Analysis of variance

Source	S.S.	D.F.	Variance	'F'
Block	34.11	4	8.527	0.63
Legumes	496.83	2	248.415	18.5 *
Error 1	107.24	8	13.405	-
Phosphorus	601.72	2	300.86	57.5 *
Interaction	54.63	4	13.657	2.6
Error 2	125.45	24	5.227	-

* Significant at 5 per cent level.

APPENDIX VII

Difference between total nitrogen in the soil---Analysis of variance.

Source.	S.S.	D.F.	Variance.	'F'
Block	0.00000076	4	0.00000019	2.2
Legumes	0.00000424	2	0.0000021	24.42*
Error 1	0.00000069	8	0.000000086	---
Phosphorus	0.00000463	2	0.00000232	9.28*
Interaction	0.00000031	4	0.0000000775	0.31
Error 2	0.00000591	24	0.00000025	---

* Significant at five per cent level.

APPENDIX VIII

Height of ragi at 60 days - Analysis of variance

Source.	S.S.	D.F.	Variance	'F'
Block	30.23	4	7.55	2.46
Legumes	2712.43	3	904.16	295.47*
Error 1	36.75	12	3.06	—
Phosphorus	5.31	2	2.65	1.51
Interaction	93.66	6	15.61	8.92*
Error 2	55.90	32	1.75	—

* Significant at five per cent level.

APPENDIX IX

Tiller count of Ragi - Analysis of variance

Source.	S.S.	D.F.	Variance	'F'
Block	7.25	4	1.81	13.92*
Legumes	28.24	3	9.41	72.38*
Error 1	1.56	12	0.13	---
Phosphorus	12.16	2	6.08	164.30*
Interaction	0.77	6	0.128	3.40
Error 2	1.19	32	0.037	---

* Significant at five per cent level.

APPENDIX X

Yield of grain in Kilograms--Analysis of variance

Source	S.S.	D.F.	Variance	'F'
Block	1.2877	4	0.3219	3.15
Legumes	28.7524	3	9.5841	94.12*
Error 1	1.2225	12	0.1018	---
Phosphorus	16.6778	2	8.3389	150.20*
Interaction	2.1386	6	0.3564	6.41*
Error 2	1.7784	32	0.0555	---

* Significant at five per cent level.

APPENDIX XI

Yield of straw in Kilograms per plot-Analysis of variance

Source	S.S.	D.F.	Variance.	'F'
Block	7.49	4	1.872	7.17 *
Legumes	97.35	3	32.45	124.30 *
Error 1	3.14	12	0.261	—
Phosphorus	0.10	2	0.05	1.86
Interaction	9.09	6	1.515	56.11 *
Error 2	0.89	32	0.027	—

* Significant at five per cent level.

APPENDIX XII

Nitrogen content of Ragi grain--Analysis of variance

Source.	S.S.	D.F.	Variance.	'F'
Block	0.0065	4	0.00112	0.933
Legumes	0.0053	3	0.00172	1.46
Error 1	0.0148	12	0.00120	—
Phosphorus	0.0010	2	0.00050	2.94
Interaction	0.0024	6	0.0004	2.35
Error 2	0.0057	32	0.00017	—

APPENDIX XIII

Nitrogen content of Ragi straw - Analysis of variance

Source	S.S.	D.F.	Variance	'F'
Block	0.000299	4	0.000074	1.17
Legumes	0.000565	3	0.000188	3.08
Error 1	0.000757	12	0.000063	---
Phosphorus	0.000952	2	0.000476	3.06
Interaction	0.000509	6	0.000084	0.70
Error 2	0.003834	32	0.000120	---

APPENDIX XIV

Phosphorus content of Ragi grain - Analysis of variance.

Source	S.S.	D.F.	Variance.	'F'
Block	0.0021	4	0.0005	1.21
Legumes	0.0020	3	0.0006	1.46
Error 1	0.0050	12	0.00041	—
Phosphorus	0.003	2	0.0015	2.5
Interaction	0.002	6	0.0003	0.5
Error 2	0.021	32	0.0006	—

APPENDIX XV

Phosphorus content of Ragi straw - Analysis of variance

Source	S.S.	D.F.	Variance	'F'
Block	0.000246	4	0.0000615	1.53
Legumes	0.0000889	3	0.0000296	0.715
Error 1	0.000475	12	0.000040	—
Phosphorus	0.000320	2	0.000160	0.015
Interaction	0.00063	6	0.0000105	0.0010
Error 2	0.35127	32	0.010977	—

APPENDIX XVI

Meteorological data for the period of crop growth

Month		Mean temperature in °C	Relative humidity %	Total fain fall in mm.
June	1963	27.6	91.8	50.5
July	"	26.6	92.3	91.5
August	"	27.4	90.8	168.0
September	"	28.0	90.1	137.0
October	"	27.0	90.8	215.5
November	"	27.0	89.8	184.5
December	"	27.0	92.3	52.0
January	1964	26.7	97.0	..
February	"	28.4	90.8	38.0
March	"	28.7	91.8	36.0

ILLUSTRATIONS

FIGURE 9

Straw yield in kilograms per acre

G_1 - *Sesbania speciosa*-incorporated

G_2 - *Crotalaria juncea* "

G_3 - *Crotalaria striata* "

G_4 - Control - no green manure

P_0 - No P_2O_5

P_1 - 20 lb. P_2O_5 per acre

P_2 - 40 lb. P_2O_5 per acre

FIGURE 8

Grain yield in kilograms per acre.

G_1 - Sesbania speciosa-incorporated

G_2 - Crotalaria juncea "

G_3 - Crotalaria striata "

G_4 - Control - no green manure

P_0 - No P_2O_5

P_1 - 20 lb. P_2O_5 per acre

P_2 - 40 lb. P_2O_5 per acre

FIGURE 6

Height of ragi on 60th day

G_1 - Sesbania speciosa-incorporated

G_2 - Crotalaria juncea "

G_3 - Crotalaria striata "

G_4 - Control - no green manure

P_0 - No P_2O_5

P_1 - 20 lb. P_2O_5 per acre

P_2 - 40 lb. P_2O_5 per acre

FIGURE 7

Number of tillers per plant.

(Treatments same as above)

FIGURE 4 & 5

Green and dry matter yield of green manures.

G_1	-	Sesbania speciosa
G_2	-	Crotalaria juncea
G_3	-	Crotalaria striata
G_4	-	Control--no green manure
P_0	-	No P_2O_5
P_1	-	20 lb. P_2O_5 per acre
P_2	-	40 lb. P_2O_5 per acre

FIGURE 3

Nodule counts

G_1 - *Sesbania speciosa*

G_2 - *Crotalaria juncea*

G_3 - *Crotalaria striata*

G_4 - Control--no green manure

P_0 - No P_2O_5

P_1 - 20 lb. P_2O_5 per acre

P_2 - 40 lb. P_2O_5 per acre

FIGURE 2

Height of green manures

G_1	-	*Sesbania speciosa*
G_2	-	*Crotalaria juncea*
G_3	-	*Crotalaria striata*
G_4	-	Control - no green manure
P_0	-	No P_2O_5
P_1	-	20 lb. P_2O_5 per acre
P_2	-	40 lb. P_2O_5 per acre

FIGURE 1

Layout of the Experiment

G_1 - *Sesbania speciosa*

G_2 - *Crotalaria juncea*

G_3 - *Crotalaria striata*

G_4 - Control - no green manure

P_0 - No P_2O_5

P_1 - 20 lb. P_2O_5 per acre

P_2 - 40 lb. P_2O_5 per acre

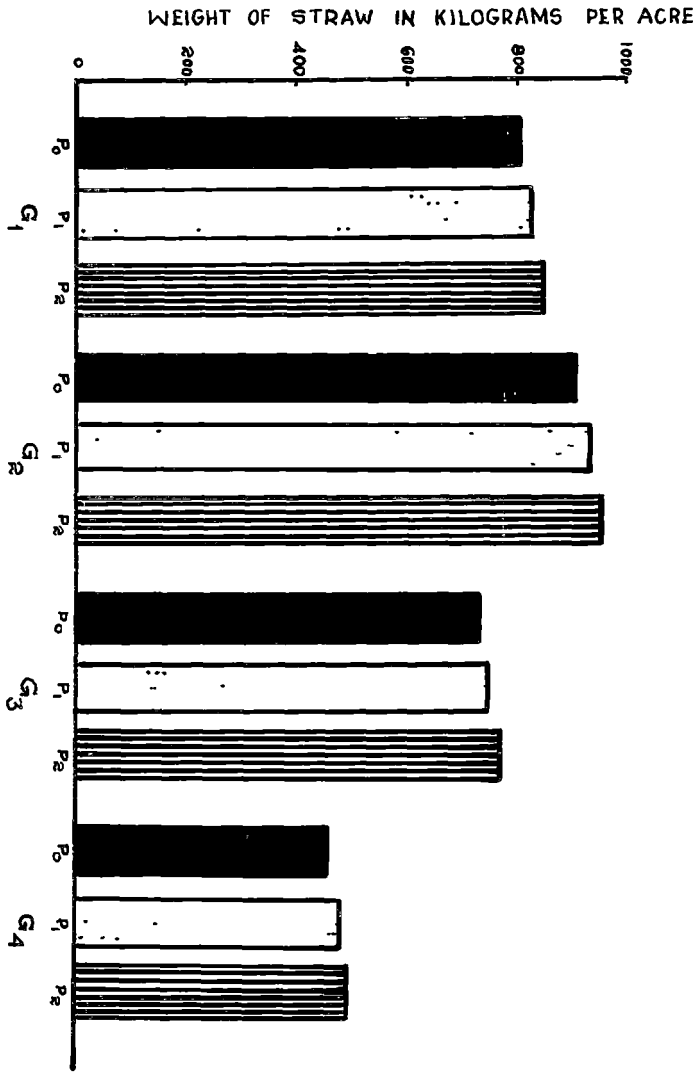

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PLATE I

- Sesbania speciosa incorporated. P_0-No P_2O_5.

PLATE II

bania speciosa incorporated. P_1-20 lb. P_2O_5/ac

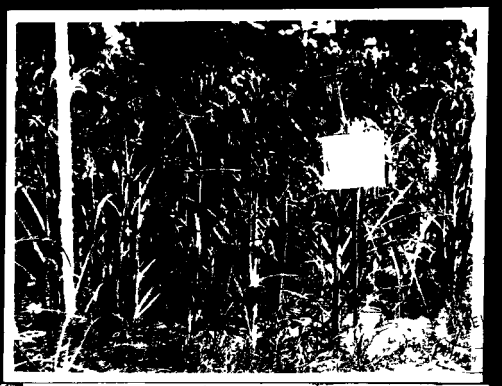

PLATE III

G_1-Sesbania speciosa incorporated.P_2-40 lb.P_2O_5/ac.

PLATE IV

G_2-Crotalaria juncea incorporated.P_0-No P_2O_5.

PLATE V

C_2-Crotalaria juncea incorporated.P_1-20 lb.P_2O_5/ac.

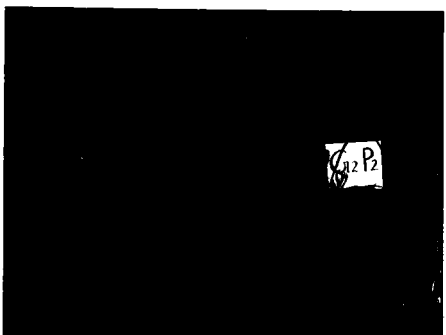

PLATE VI

C_2-Crotalaria juncea incorporated.P_2-40 lb.P_2O_5/ac.

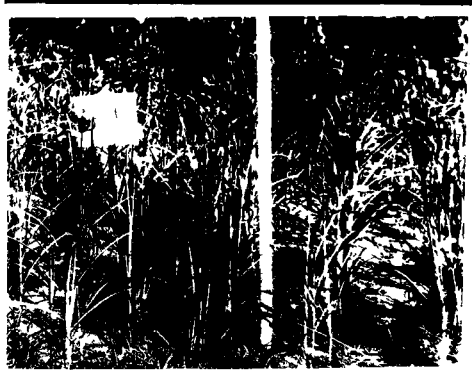

PLATE VII

G_5-Crotalaria striata incorporated. P_0-No P_2O_5

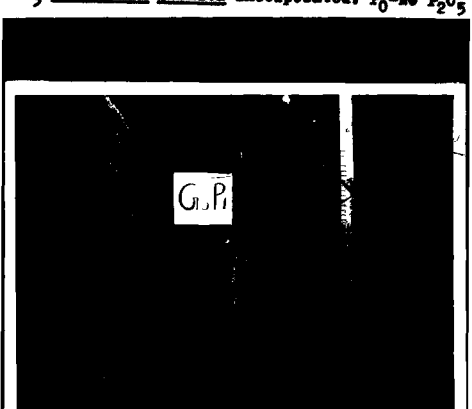

PLATE VIII

G_5-Crotalaria striata incorporated, P_1-20 lb. P_2O_5/

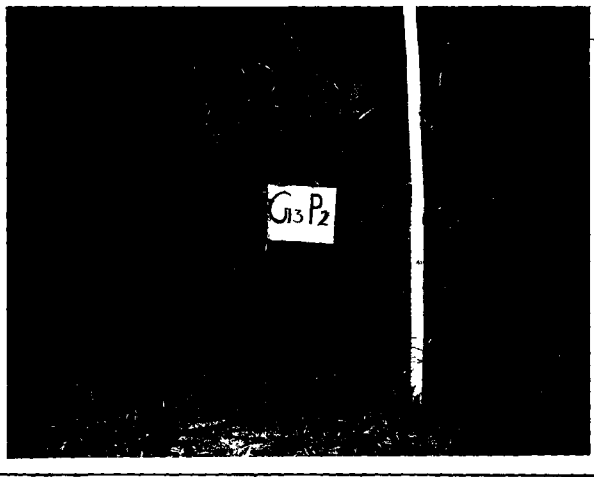

PLATE IX

G_3-Crotalaria striata incorporated. P_2-40 lb. P_2O_5/ac.

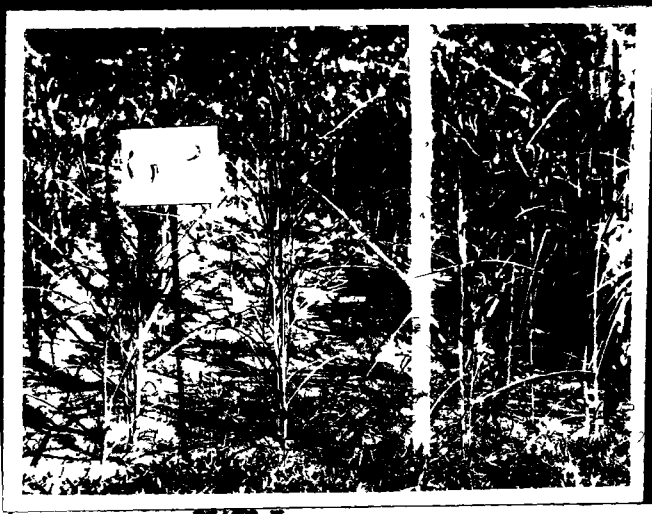

PLATE X

G_4-No legume. P_0-No P_2O_5.

PLATE XI

G_4-No legume.P_1-20 lb.P_2O_5/ac.

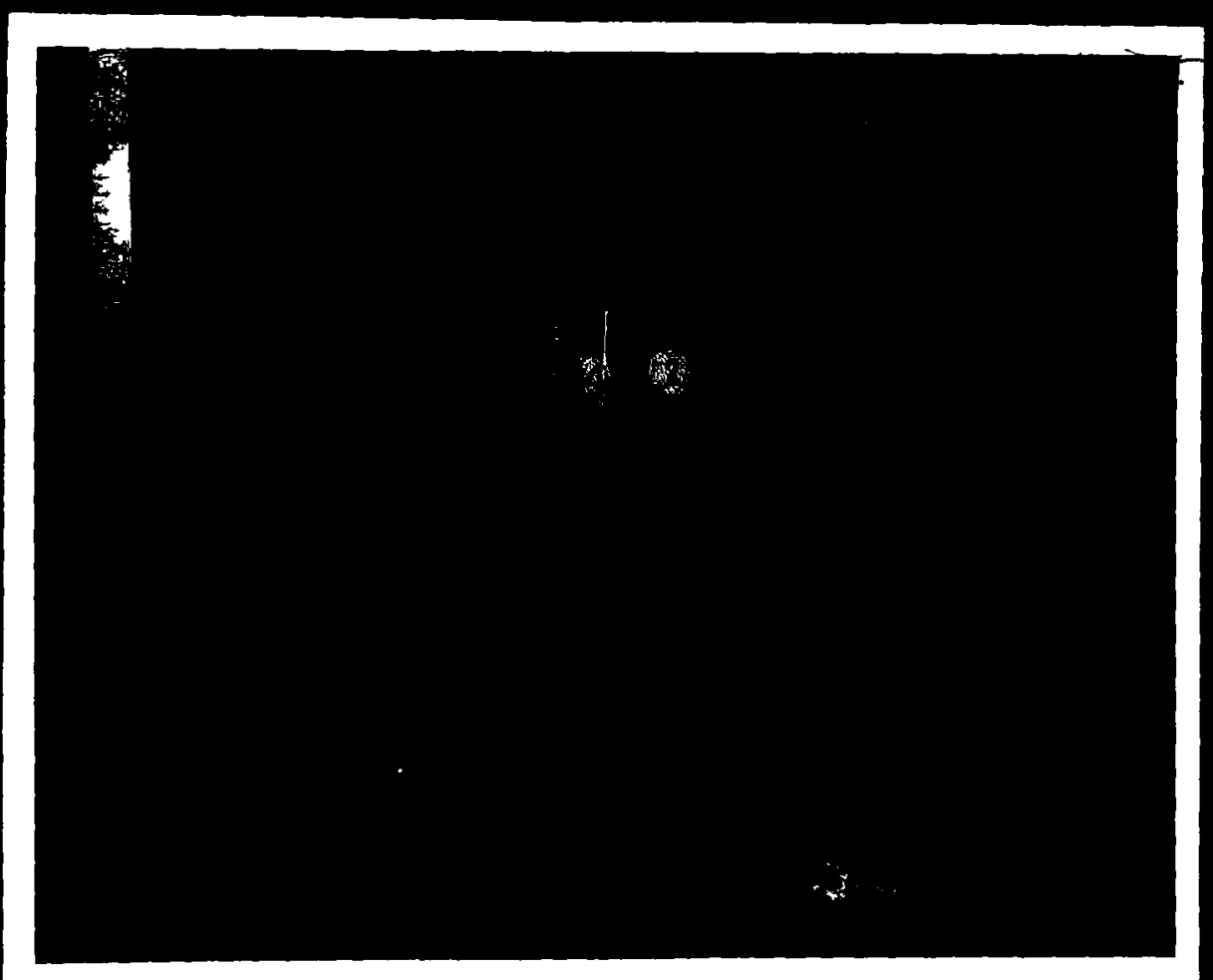

PLATE XII

C_4-No legume.P_2-40 lb.P_2O_5/ac.