BIOMASS PRODUCTIVITY AND NUTRIENT ACCUMULATION IN *Sesbania rostrata* INOCULATED WITH *Rhizobium*

BY

MURALI S.

THESIS

submitted in partial fulfilment of the

requirement for the Degree of

MASTER OF SCIENCE IN AGRICULTURE

Faculty of Agriculture

Kerala Agricultural University

Department of Agronomy

COLLEGE OF AGRICULTURE

VELLAYANI, TRIVANDRUM

1989

Dedicated to my beloved mother
and grand parents

DECLARATION

I hereby declare that this thesis entitled "Biomass productivity and nutrient accumulation in Sesbania rostrata inoculated with Rhizobium" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Vellayani,
20 June, 1989.

MURALI, S.

CERTIFICATE

Certified that this thesis entitled "Biomass productivity and nutrient accumulation in *Sesbania rostrata* inoculated with *Rhizobium* " is a record of research work done independently by Shri.Murali, S. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

Vellayani,
20June, 1989.

Dr.V.MURALEEDHARAN NAIR
Chairman
Advisory Committee
Professor of Agronomy
College of Agriculture

APPROVED BY:

CHAIRMAN:

Dr.V.MURALEEDHARAN NAIR

MEMBERS:

1. Shri.K.P. MADHAVAN NAIR

2. Dr.P.SIVAPRASAD

3. Dr.(Mrs.) P.SARASWATHY

EXTERNAL EXAMINER

8/9/89

Dr.M.R.IRUTHAYARAJ
Professor of Agronomy,
Water Technology Centre,
TNAU., Coimbatore.

ACKNOWLEDGEMENT

The author wishes to place on record his deep sense of gratitude and indebtness to:

Dr.V.Muraleedharan Nair, Professor of Agronomy, College of Agriculture, Vellayani and Chairman of Advisory Committee for his valuable guidance, inspiring encouragement and constructive criticisms which contributed most to the completion of the study;

Shri K.P.Madhavan Nair, Professor of Agronomy, College of Agriculture, Vellayani for his encouragement, helpful suggestions, critical scrutiny of the manuscript and for the keen interest shown throughout the study;

Dr.P.Sivaprasad, Associate Professor of Plant Pathology, College of Agriculture, Vellayani, for his unstinted interest and untiring help at all stages of work;

Dr.(Mrs.) P.Saraswathy, Professor, Department of Agricultural Statistics, College of Agriculture,Vellayani for her valuable guidance in connection with the designing of the experiment and interpretation of the experimental data;

Shri.C.T.Sreekumar, Shri.Ravikrishnan, M.K., Shri.Viswakumar, P., Shri.Rajan, S., Post-graduate scholars for their friendly co-operation and assistance rendered at various stages of the work;

the teaching and non-teaching staff of the Department of Agronomy, College of Agriculture, Vellayani for their sincere support extended throughout the course of this investigation;

the Kerala Agricultural University for awarding a fellowship for the Post-graduate programme,

and his uncles' and aunts' without whose patronage this thesis would never have seen the light of the day.

Vellayani,
20 June, 1989.

MURALI, S.

C O N T E N T S

LIST OF TABLES

LIST OF APPENDICES

LIST OF ILLUSTRATIONS

LIST OF PLATES

--

LIST OF ABBREVIATIONS

cm	-	centimetre
m	-	metre
mm	-	millimetre
g	-	gram
t	-	tonnes
ha	-	hectare
kg	-	kilogram
^{o}C	-	degree celsius
DAS	-	days after sowing
DAE	-	days after emergence
Fig.	-	figure
No.	-	number
GMP	-	green matter production
DMP	-	dry matter production
KAU	-	Kerala Agricultural University
TNAU	-	Tamil Nadu Agricultural University
IRRI	-	International Rice Research Institute

INTRODUCTION

INTRODUCTION

In India, the use of nitrogenous fertilizers prior to Green revolution was restricted mostly to government agriculture farms and research stations. The 1960's witnessed the advent of Green revolution in India, which was characterized by the introduction of high yielding varieties of cereals, especially rice and wheat and widespread use of inorganic nitrogen. Nitrogen is the 'King pin' of agriculture. The success of Green revolution brought about an unprecedented demand for nitrogenous fertilizers. Rapid industrialization was mooted to meet the demand and subsequently fertilizer production gained momentum. But the use of inorganic nitrogenous fertilizer has not filtered down to small and marginal farmers of India, due to high cost of production. This necessitated the need to search for an alternate cheap source of nitrogen. Green manures and biofertilizers as an alternate source of nitrogen assume paramount importance in this context.

Green manuring can be defined as the growing of a crop for the specific purpose of incorporating into soil while green,with a view to improve the fertility status of soil and for the benefit of subsequent crops.

The objectives of green manuring are to increase the organic matter content of soils, to maintain and improve soil structure, to reduce loss of nutrients particularly nitrogen, to provide a source of nitrogen for the succeeding crop and to reduce soil loss by erosion. These are very worthy aims in any agricultural system and are particularly appealing at the present time when genuine concern is being expressed in a number of quarters on the environmental problems associated with intensive agriculture.

Symbiotic nitrogen fixation by leguminous green manures (LGM) crops can provide a substantial portion of nitrogen required by crop plants, especially rice. It's role in achieving and maintaining ecological sustainability in tropical farming systems is expected to increase. Green manure crop production could be a viable component of integrated nutrient management to obtain higher agronomic yields.

Several types of LGM crops have been used as nitrogen sources. Vachhani and Murty(1964) surveyed about 100 LGM crops and concluded that Crotolaria juncea and Sesbania aculeata were most acceptable to farmers in Asia, especially India. Sesbania spp are ideal green manures as they can grow in a wide range of eco-geographical regions and on different types of soil. Recently Sesbania rostrata, a LGM has aroused great interest as a promising biological nitrogen fixing plant. It is a native of Senegal, West Africa (Dreyfus *et al* 1985), and is capable of flourishing in water logged soils. The plant bears nitrogen fixing nodules on roots and stems at the same time and they are five to ten times more in number than in other legumes. This plant is sturdy and can grow in wide range of soil moisture conditions (Saint Macary *et al* 1985). The plant can pick up *Rhizobium* bacteria from an aerial spray inoculant. It is capable of fixing nitrogen even under high inorganic nitrogen levels in soil, a trait not seen in other LGM (Rinaudo *et al* 1982a; 1983). Unlike other legumes, *Sesbania rostrata* can grow well in saline and alkaline soils. The plant is free from attack of pests and pathogens. But it seems to have some specific disadvantages, in the form of photoperiod sesnsitivity and seed dormancy.

The advantageous traits exhibited by *Sesbania rostrata* clearly outweighs the disadvantages shown in the form of seed dormancy and photoperiod sensitivity. In Kerala, production and use of green manures is limited. The use of farm yard manure has also declined substantially, due to its low availability and high cost. Very little work has been done in Kerala on green manures, especially

Sesbania rostrata, with respect to its climatic and soil requirements and management practices. Keeping the above views in mind, this investigation was mainly intended as a preliminary study, to find out the adaptability of Sesbania rostrata to local conditions. The investigation was carried out as two separate experiments with the following objectives:

(i) to determine the biomass productivity and nutrient accumulation of Sesbania rostrata in relation to other green manures viz. Sesbania aculeata and Crotolaria juncea.

(ii) to study the effect of liming, Rhizobium inoculation and phosphorus application on biomass productivity and nitrogen accumulation by Sesbania rostrata in acid soils.

(iii) to study the economics of utilization of Sesbania rostrata as a green manure.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The present investigation is to study the biomass productivity and nitrogen accumulation of *Sesbania rostrata* in comparison to other green manures and the effect of liming, phosphorus application and *Rhizobium* inoculation on the biomass production and nutrient accumulation of *Sesbania rostrata*. Works in these lines are meagre. The review given below relates to studies which have a bearing on the present investigation(s).

2.1 Growth characteristics

2.1.1 Plant height

Plant height is one of the indices for measuring growth Tisdale *et al*.(1985). He reported that, the height of plants will increase, as their age increases, until the maturity stage; thereafter height will remain constant.

Bindumadhava Rao and Venkatesan (1965) from Aduthurai reported that *Sesbania speciosa* plants attained a height of 3.5 m, at 49 DAS (flowering stage). Dreyfus *et al*.(1985) observed that *Sesbania rostrata* plants grew upto 1.5 m at 50 DAS. Similar observations were made by Singh *et al*.(1988) on *Sesbania rostrata* and

Sharma and Murty (1988) on *Sesbania rostrata* and *Sesbania aculeata*.

2.1.2 Total green matter yield

Yield is the final product which indicates the potentiality of a particular plant species and is the yard stick to measure the superiority of one plant species over the other.

Khind *et al.*(1983) observed an increase in green matter production in *Sesbania aculeata* with increase in age from 30 to 60 DAS. Rajbhandari (1984) obtained fresh matter yields of 1.3, 8.0 and 13.3 t/ha from *Sesbania* aculeata at 24, 36 and 48 days after sowing. Batra (1985) obtained 141.4 g fresh weight/pot, 55 days after sowing for *Sesbania aculeata*. Bharadwaj and Dev (1985) obtained a progressive increase in green matter yield (18.2 to 37.1t/ha) of *Sesbania aculeata*, when the days of harvest were delayed from 45 to 65 days after sowing. Dreyfus *et al*.(1985) obtained a fresh matter yield of 20 t/ha for *Sesbania* rostrata, 50 days after sowing. Meelu *et al*.(1985a) evaluated *Sesbania aculeata*, *Crotolaria juncea*, soybean, lab-lab, pigeon pea and indigo as green manures. They observed that *Sesbania aculeata* produced 21.0 and 33.4 t/ha of fresh matter at 30 and 45 DAS, respectively. In another experiment Meelu *et al*.(1985b) obtained a fresh matter yield of 34.6 t/ha in 60 days for *Sesbania aculeata*. Meelu *et al*.

(1986), while evaluating the performance of eight green manure crops in Philippines, obtained an average value of 24.0 and 38.8 t/ha of fresh matter for *S. aculeata* over two years in 60 day duration. Joseph (1986) obtained a green matter yield of 25.0 t/ha for *Sesbania aculeata* in 60 days. Studies on green manuring of rice in farmers' field by Gines *et al.* (1987) in Philippines, revealed that 45 day old *Sesbania rostrata* plants produced 12-17 t/ha of green matter. While evaluating the productivity of 25 Sesbania spp for green manuring, Evans and Rotar (1987) at the University of Hawaii obtained green matter yields of 54.8 and 35.9 t/ha for *Sesbania cannabina* and *Sesbania* rostrata respectively in a duration of 14 weeks.

Experiments conducted at Tamil Nadu Agricultural University, Coimbatore revealed that *Sesbania rostrata* produced a green matter yield of 19.0, 31.2 and 46.0 t/ha at 30, 45 and 60 days after sowing, whereas Crotolaria juncea produced 9.0, 14.0 and 16.5 t/ha at 30, 45 and 60 days after sowing (Anon, 1988). Ghai *et al* (1988) obtained a fresh matter yield of 25.0 t/ha for *Sesbania aculeata*, in 45 days grown in a soil of pH 9.5

Beri *et al.*(1989) studied the biomass production of *Sesbania aculeata* and *Crotolaria juncea* in relation to yield of wetland rice. He observed that 60 day old

Sesbania aculeata produced 20.0 t/ha of green matter whereas, *Crotolaria juncea* produced 21.0 t/ha of green matter during the same period.

2.1.3 Total dry matter production

Nair *et al*.(1970) from a field experiment reported that *Crotolaria juncea* produced 10.8 t/ha dry matter in 55 days. Bronson (1983) obtained a dry matter yield of 1.33 t/ha from *Sesbania rostrata* at 40 days after emergence. Khind *et al*.(1983) observed that dry matter production of daincha increased with age upto flowering (60 DAS). Rajbhandari (1984) obtained 0.27, 1.7 and 4.9 t/ha from *Sesbania aculeata* at 24, 36 and 48 days after sowing. Field experiments at IRRI, Philippines revealed that a 45 day old *Sesbania rostrata* produced 6.3 tons dry matter per hectare (Anon, 1985). Bharadwaj and Dev (1985) reported that *Sesbania aculeata* produced 3.1, 5.3 and 7.3 t/ha of dry matter at 45, 55 and 65 days after sowing. Meelu *et al*. (1985a) in his evaluation of different green manures observed that *Sesbania aculeata* produced 2.8, 6.6 and 9.9 t/ha of dry matter at 30, 45 and 60 days after sowing. Meelu *et al*.(1985b) also obtained 5.8 t/ha dry matter at 60 days after sowing in another experiment. Furoc *et al*. (1985) determined the biomass production of spp, *Sesbania rostrata*, *Sesbania aculeata* and *Sesbania* "China type".

Dry matter yields were 7.7, 7.2 and 6.9 t/ha respectively at 61 days after planting. At 49 day growth, dry matter yields were 2.6 t/ha for S. rostrata, 2.5 t/ha for S. aculeata and 2.7 t/ha for Sesbania "China type". Meelu et al.(1986) while evaluating the performance of eight green manure crops in Philippines obtained an average value of 3.4 and 9.0 t/ha of dry matter over two years, of S. aculeata at 60 days after sowing. Yamada et al.(1986) in Japan concluded that Crotolaria juncea produced 8.09 t/ha of dry matter in 60 days growth period. Mulongoy (1986) while observing the potential of Sesbania rostrata as nitrogen source in alley cropping systems obtained a dry matter yield of 4.0 t/ha when planted as an alley crop with rice. In his studies on green manuring of rice in farmers' fields in Philippines, Gines et al.(1987) obtained 1.5 -3.0 t/ha of dry matter for Sesbania rostrata at 45 days after sowing. Evans and Rotar (1987) at the University of Hawaii obtained dry matter yield of 17.0 and 12.1 t/ha for Sesbania cannabina and Sesbania rostrata respectively in a duration of 14 weeks. Ventura et al.(1987) from IRRI observed that 47 day old Sesbania rostrata produced 3.97 t/ha of dry matter. In a pot experiment Sharma and Murty (1988) found that Sesbania rostrata produced 2.4 and 13.7 g dry weight/plant during the dry and wet seasons respectively, whereas Crotolaria juncea produced 1.7 and 6.0 g dry weight/plant during the same periods. Beri et al.(1989)

in their study on biomass production of *Crotolaria juncea* and *Sesbania* spp observed that *C. juncea* produced 6.9 t/ha and *Sesbania* spp 5.4 t/ha of dry matter at 60 days after sowing.

2.1.4 Nodulation

Nodulation is the main index of symbiotic nitrogen fixing efficiency in legumes. The extent of nodulation is generally assessed by the number and weight of nodules produced by each species.

2.1.4.1 Root nodulation characteristics

Nair *et al*.(1970) from a field experiment concluded that *Sesbania aculeata* produced 69 root nodules/plant in 60 days whereas *Crotolaria juncea* produced 50 root nodules/plant in 55 days.

Dreyfus *et al*.(1985) observed that *Sesbania rostrata* produced on an average 2 to 4 g of fresh weight of root nodules per plant. From a field experiment at Punjab Agricultural University, Singh *et al*.(1985) reported that root nodule number increased with time in *Sesbania aculeata* and at 59 days after sowing, the root nodule number per plant was 45 to 50 and the fresh weight 113.70 mg/plant. They also observed that root nodule weight at 59 DAS was about five times than its weight in 31 days. An experiment at IRRI revealed that uninoculated

Sesbania rostrata plants produced an average of 26 root nodules/plant (Anon, 1986).

From a field experiment conducted in the uplands at IRRI, Hati (1987) reported that 20 day old *Sesbania rostrata* plants produced an average of 7 to 17 root nodules/plant.

Field experiments at TNAU, Coimbatore revealed that *Sesbania rostrata* produced 14,38 and 31 root nodules/plant at 30,45 and 60 DAS. The corresponding fresh weight of the root nodules were 9.6, 28.7 and 64.8 mg/plant respectively (Anon, 1988).

2.1.4.2 Stem nodulation characteristics

Sesbania rostrata occupies a unique position along with *Aeschynomene* spp among leguminous green manures as it produces both root and stem nodules. Stem nodules on *Sesbania rostrata* are ovoids, contain chlorophyll and have determinate growth (Eaglesham and Szalay, 1983).

Field trial at International Institute of Tropical Agriculture revealed that *Sesbania rostrata* produced on an average 2000 - 3000 stem nodules/plant (Anon, 1983).

Dreyfus *et al*. (1985) from field experiments in Senegal, West Africa reported that *Sesbania rostrata*, produced on an average 30-40 g fresh weight of stem nodules per plant.

An experiment conducted IRRI revealed that uninoculated *Sesbania rostrata* plants failed to produce any stem nodules (Anon, 1986).

Yin and Lu (1987) at Nanjing Agricultural University, China concluded that *Sesbania rostrata* produced 2-3 times more stem nodules than root nodules and stem nodules fixed 46 times as much nitrogen per plant as root nodules.

Evans and Rotar (1987) from a field experiment at University of Hawaii reported that *Sesbania rostrata* failed to produce any stem nodules during its 14 week growth period.

Field experiments TNAU, Coimbatore revealed that stem nodulation in *Sesbania rostrata* occured on 35th day after sowing and a 45 day old plant produced 162 nodules/stem and 60 day old plant 470 nodules/stem, with the corresponding fresh weights as 134.5 and 486.2 mg/plant respectively (Anon, 1988).

The above review reveals that stem nodulation in *Sesbania rostrata* is highly irregular and may be dependent on the climatic and soil conditions of a given location.

2.2 Chemical composition

2.2.1 Nitrogen content of nodules

Investigations on Sesbania rostrata at TNAU, Coimbatore revealed that root nodules contained, 0.95, 1.38 and 1.24 per cent nitrogen at 30, 45 and 60 DAS, whereas stem nodules contained 1.44 and 1.89 per cent nitrogen at 45 and 60 DAS (Anon, 1988).

2.2.2 Nutrient content of the green manures

Alonso (1934) compared nine green manure crops for N and P content and yield. He reported that nitrogen and phosphorus concentrations of legume plants decreased towards maturity.

Hernandez and Coloma (1957) evaluated 11 green manure legumes and concluded that nitrogen percentage ranged from 2.4 per cent in calapogonium to 5.7 per cent in 'ipil-ipil'.

Hernandez *et al*.(1957) evaluated 14 legume green manures for nitrogen content. Nitrogen concentration was the highest at 45 days and ranged from 1.76 per cent in Crotolaria juncea to 3.67 per cent in Tephrosia candida. They observed that nitrogen content generally decreased with plant age.

Mello and De (1978) evaluated four legume green manures in Brazil and reported that *Crotolaria juncea* contained 1.77 per cent nitrogen and *Stizolobium aterssmum* 2.78 per cent nitrogen at maturity.

Ghai *et al*.(1984) observed that *Sesbania aculeata* contained 3.85 per cent nitrogen at 45 days of growth.

Rajbhandari (1984) reported that nitrogen content decreased with age in *Sesbania aculeata* from 3.68 at 24 DAS to 1.58 per cent at 48 DAS.

Bharadwaj and Dev (1985) found that nitrogen content of *Sesbania cannabina* decreased with age from 3.12 per cent at 45 DAS to 2.25 per cent at 65 DAS.

Reports from IRRI, Philippines indicated that 45 day old *Sesbania rostrata* plants contained 3.81 per cent N, 0.22 per cent P and 3.23 per cent K on dry weight basis (Anon, 1986).

Joseph (1986) observed that 60 day old *Sesbania aculeata* plants contained 2.0 per cent N, 0.7 per cent P and 1.1 per cent K on dry matter basis.

Ventura *et al*.(1987) from IRRI reported that 47 day old *Sesbania rostrata* plants contained 2.0 per cent nitrogen on dry weight basis.

Hundal *et al*.(1988) concluded that 45 day old *Sesbania aculeata* and *Crotolaria juncea* contained 2.63 and 2.87 per cent nitrogen and 0.35 and 0.38 per cent phosphorus, respectively.

2.3 Nitrogen yield of the green manures

Terchune (1977) observed that *Sesbania aculeata* planted along with rice accumulated 96 kg N/ha.

Mello and De (1978) evaluated the nitrogen accumulated by different legume green manures and found that *Crotolaria juncea* yielded 153.5 kg N/ha in 45 days.

Bronson (1983) reported that *Sesbania rostrata* accumulated 18 kg N/ha during 40 day growth period. Rajbhandari (1984) obtained nitrogen yields of 8, 36 and 78 kg/ha from *Sesbania aculeata* at 24, 36 and 46 DAS.

Ghai *et al*.(1984) observed that a 45 day old *Sesbania aculeata* yielded 70 kg N/ha. In another field experiment, Ghai *et al*.(1988) reported that *Sesbania aculeata* yielded 106 kg N/ha, 57 DAE.

Meelu *et al*.(1985a) obtained a nitrogen yield of 33 and 225 kg/ha from *Sesbania aculeata* at 30 and 45 days after emergence, while for *Crotolaria juncea*, they obtained a nitrogen yield of 169 kg/ha at 45 DAE.

Furoc et al.(1985) determined the nitrogen yield of three Sesbania spp. Sesbania rostrata, Sesbania aculeata and Sesbania "China type" at 49 and 61 days after planting. At 49 days growth nitrogen yields were 89, 64 and 58 kg/ha and at 61 days growth, nitrogen yields were 176, 144 and 131 kg/ha respectively for the three Sesbania spp.

Field trials at IRRI recorded a nitrogen accumulation of 262 kg/ha in 52 days, for Sesbania rostrata (Anon, 1985).

Schmidt Lepardeur and Lassavilly (1986) reported that Sesbania rostrata yielded 200 kg N/ha in 60 days.

Mulongoy (1986) reported that Sesbania rostrata accumulated 70 kg N/ha when grown as an alley crop with rice.

Chapman and Myers (1987) obtained a nitrogen accumulation of 110-130 kg/ha in Sesbania aculeata at maturity.

In a field experiment in Philippines, Morris et al. (1987) obtained a nitrogen accumulation of 219 kg/ha for Sesbania rostrata and 171 kg/ha for Sesbania cannabina at 60 DAE.

Gines et al.(1987) in their studies on green manuring of rice in farmers' fields obtained nitrogen yields ranging from 62 to 88 kg/ha from 45 day old Sesbania rostrata, whereas in replicated field experiments, *Sesbania rostrata* yielded 58 and 192 kg N/ha in 45 DAE and 60 DAE respectively.

Ventura *et al.*(1987) reported that a 47 day duration *Sesbania rostrata* yielded 79 kg N/ha.

Field trials at TNAU revealed that *Sesbania rostrata* accumulated 74, 132, 186 kg N/ha at 30, 45 and 60 DAS whereas *Sesbania aculeata* accumulated 58, 94 and 136 kg N/ha and *Crotolaria juncea* 31, 52 and 65 kg N/ha for the same periods of growth (Anon. 1988).

In an experiment to determine the nitrogen accumulation of leguminous green manures, Beri *et al*.(1989) obtained nitrogen yields of 110 kg/ha and 108 kg/ha from a 60 day old *Crotolaria juncea* and *Sesbania aculeata*.

The above review reveals that nitrogen accumulation by the green manures, especially by *Sesbania rostrata* varies widely from place to place. Even in experiments conducted in Philippines, the nitrogen yield of *Sesbania rostrata* varied from 70 kg/ha to 262 kg/ha in a crop of 45-50 day duration.

2.4 Seasonal response of the green manures

According to Dreyfus et al.(1985), at Senegal Sesbania rostrata has given the highest biomass and profuse stem nodulation during rainy months (June to September). In contrast, during the dry and cold season, growth was poor, flowering was abnormally early and nodulation was very poor. This variation in the behaviour during the different seasons can be attributed to its sensitivity to photoperiod, temperature and humidity.

Visperas et al.(1987) reported that S. rostrata was a short day plant with critical photoperiod of between 12 and 12.5 hours.

In a field experiment at IRRI, Ventura et al.(1987) observed that Sesbania rostrata was sensitive to day length period and its growth and biomass production was retarded when grown during August-October. They obtained best results (3.97 t/ha dry matter and 79 kg N/ha) when it was grown during April-June.

Osseni et al.(1987) studied the behaviour of Sesbania rostrata as a nitrogen fixing legumes under different sowing dates - Oct. 1984, Jan., May and Sept. 1985 in Southern Ivory Coast. They observed that Sesbania rostrata sown in January (hottest period of the year) gave the best results both in terms of biomass production and nitrogen yield.

Field experiment at TNAU, Coimbatore indicated that *Sesbania rostrata* gave higher biomass production and nitrogen accumulation when sown during the warmer part of the year (March-July). During cooler months, (November-February), growth and biomass accumulation were relatively poor (Anon, 1988).

2.5 Effect of lime on growth characteristics

2.5.1 Plant height

In a field experiment with different legumes, Rose (1963) found that application of lime at 600 kg per hectare increased the plant height significantly over control at all the stages of observation.

Yost *et al*.(1985) reported that height of *Crotolaria juncea* plants increased from 110 cm to 164 cm when the soil pH was increased from 4.7 to 5.9 by liming. For *Sesbania cannabina*, the plant height increased from 58 cm to 140 cm when the soil pH was increased by the same margin.

2.5.2 Green matter yield

Lowther (1975) observed that application of lime at 2.5 t/ha increased the green matter yield of many legumes.

Sarkar (1976) reported that green matter yield of *Crotolaria juncea* increased appreciably from 1.97 t/ha to 6.71 t/ha by the application of calcium and phosphorus.

Sreerama Reddy (1977) found that application of calcium appreciably increased the green matter yield of sunnhemp.

Manguiat *et al*.(1987a) from Philippines reported that increasing soil pH from 5.4 to 6.8 by lime application significantly improved green matter yield of *Sesbania rostrata*.

2.5.3 Total dry matter production

Poonia and Jhorar (1974) obtained increased dry weight of shoots in *Sesbania aculeata* with increasing rates of calcium application. Sreerama Reddy (1977) observed that dry matter yield of *Crotolaria juncea* increased with higher rates of calcium application.

Manguiat *et al*. (1987a) from Philippines reported that increasing soil pH from 5.4 to 6.8 by lime application significantly improved the dry matter yield of *Sesbania rostrata*.

2.5.4 Nodulation

Rose (1963) found that application of lime at 680 kg per hectare produced the largest number of nodules in *Sesbania speciosa* and *Sesbania aculeata*.

Dobereiner and Arruda (1967) showed that nodulation and nitrogen fixation in soybeans were improved by liming.

In an experiment with legumes, Almeida *et al.* (1973) found that the dry weight of nodules was increased significantly by liming. Danso (1975) observed that the application of lime increased nodulation in different legumes.

Manguiat *et al.* (1987a) from Philippines reported that nitrogen fixing efficiency of stem nodules of *Sesbania rostrata* increased by application of lime.

Investigation by Sprent *et al.*(1987) revealed that appreciable quantities of calcium should be transported in to the plants for proper nodulation.

2.5.6 Chemical composition and nutrient uptake

In an experiment cowpea, groundnut, *Sesbania speciosa* and *Sesbania aculeata*, Rose (1963) observed that application of lime at the rate of 680 kg per hectare increased the nitrogen content in plant parts.

Robson *et al.*(1970) reported that phosphorus uptake by annual legume was increased significantly by the application of lime.

Elpete (1972) found that the uptake of nitrogen by legumes was increased significantly by liming an acid soil by which the pH was shifted from 6.0 to 7.0.

Poonia and Jhorar (1974) observed that in dhaincha application of lime decreased the phosphorus content in the plant.

Munns and Fox (1977) concluded that application of lime ranging from zero to 22 t/ha increased the nitrogen content in cowpea and some other legumes.

2.5.7 *Rhizobium* population in rhizosphere

Wilson (1926) observed that *Rhizobium* population densities are commonly low in acid soils.

Vincent and Waters (1954) obtained increases in nodulation in many legumes on an acid soil by increasing inoculum levels.

Vincent (1958) reported that soil acidity had a detrimental effect on the survival of clover nodule bacteria.

Loneragan and Dowling (1958) observed that the *Rhizobium* bacteria is more affected by low soil pH than the host (legume) plant, in as much as the host can grow in soils in which *Rhizobium* bacteria perish rapidly.

Jones (1966) reported that liming acid soils improves greatly the survival of root nodule bacteria.

Danso (1975) observed that addition of one per cent lime improved greatly, the survival of *Rhizobium meliloti* strain.

The review of literatures on the effect of lime application reveals that it helps in the better nutrition of the legumes resulting in increased growth and higher green and dry matter production. Further it also stimulates symbiotic nitrogen fixing activity by neutralising soil acidity and creating a congenial environment for the micro-organisms.

2.6 Effect of inoculation on growth characters

Many authors have reported the favourable influence of *Rhizobium* inoculation on *Sesbania rostrata* in both jar and pot experiments. However the response of *Sesbania rostrata* to inoculation in the field was varied and greatly complicated by climatic, weather and soil factors.

2.6.1 Green matter production

Daroy *et al*. (1987) observed that inoculation of *Sesbania rostrata* with *Rhizobium* sp ORS 571 significantly influenced plant biomass in pot and jar experiments. They also reported that stem inoculation was a must for dry sown *Sesbania rostrata* in uplands for increasing the biomass production.

Investigations by Manguiat *et al.*(1987a) revealed that inoculation increased the biomass production of *Sesbania rostrata* by as much as 93 per cent, thereby substantially increasing its biofertilization potential. Similar results were observed by Manguiat *et al.*(1987b); they also found that in unlimed soil, inoculation was effective only at lower level of phosphorus fertilization.

2.6.2 Nodulation characteristics

Tripathi and Edward (1978) found that seed inoculation increased nitrogen fixation in all legumes.

Dreyfus *et al.* (1985) reported that *Sesbania rostrata* plants were capable of picking up an aerial spray of specific *Rhizobium* ORS 571. They observed that spraying a liquid culture of specific *Rhizobium* ORS 571 on the shoots gave increase stem nodulation and increased the efficiency of nitrogen fixation by stem nodules. They also observed that properly inoculated *Sesbania rostrata* plants could accumulate upto 200 kg N/ha during its growth period.

Daroy *et al*. (1987) reported that inoculation significantly increased the nodule number and nodule biomass of *Sesbania rostrata* in pot experiments. They concluded that under flooded systems, root inoculation alone was sufficient to induce both root and stem nodules within 40 days after seeding whereas both root and stem inoculation was needed in unflooded situations.

Manguiat *et al*. (1987b) observed that inoculation increased significantly the stem nodule nitrogen fixation.

2.7 Effect of phosphorus application on growth characteristics

2.7.1 Biomass production

Manguiat *et al*. (1987b) observed that phosphorus fertilization significantly improved the biomass production of *Sesbania rostrata*.

2.7.2 Nodulation and nitrogen fixation

Jakobsen (1985) reported that phosphorus application significantly increased the dry weight of root nodules in pea plants.

Manguiat *et al*. (1987b) observed that in *Sesbania rostrata* best growth and stem nodulation were obtained with 60 kg P_2O_5/ha while for root nodulation, 30 kg P_2O_5/ha was sufficient. They have also reported that in a limed soil the phosphorus requirement can be reduced for maximum stem nodule nitrogen fixation, if *Rhizobium* inoculation is employed. For uninoculated treatment in limed soil, higher levels of phosphorus was required.

2.8 Effect of green manures on soil characteristics

Sharma *et al.*(1988) observed that growing of *Sesbania* spp and *Crotolaria juncea* continuously for three years, decreased soil pH, but did not bring about any change in the organic carbon content of the soil in the north-western plains of India.

MATERIALS AND METHODS

MATERIALS AND METHODS

An investigation was carried out with the objective of determining the biomass productivity and nutrient accumulation of Sesbania rostrata. This investigation was carried out as two separate experiments, the details of which are given below.

Experiment I

To assess the biomass productivity and nutrient accumulation of Sesbania rostrata in relation to other green manures.

Experiment II

To determine the effect of Rhizobium inoculation, liming and phosphorus application on the biomass productivity of Sesbania rostrata in the acid soils of Kerala.

Both the experiments were carried out during the summer season of 1988-89 (from December 12, 1988 to February1, 1989). The details of the materials used and the methods adopted for the study are presented in this chapter.

3.1 MATERIALS

3.1.1 Experimental site

The experimental site(s) was located at the Instructional Farm attached to the College of Agriculture, Vellayani. The farm is located at 8.5^{O}N latitude and 76.9^{O}E longitude at an altitude of 29 m above mean sea level.

3.1.2 Soil

The soil of the experimental area is sandy clay loam. The data on the physico-chemical properties of the soil of the experimental site are given below.

Table 1. Physico-chemical properties

Constituent	Content in soil (%)	Rating	Method used
A. Mechanical composition			
Coarse sand	46.0		
Fine sand	10.4		Bouyoucos hydrometer method (Bouyoucos 1962)
Silt	6.6		
Clay	33.0		
Textural class	sandy clay loam		
B. Chemical composition			
Total nitrogen	2100 kg/ha		Modified Microkjeldahl method (jackson,1973)
Available nitrogen	170 kg/ha	Low	Alkaline potassium permanganate method (Subbiah and Asija 1956)

Constituent	Content in soil (%)	Rating	Method used
Available phosphorus	20.95 kg/ha	Low	Braycolorimetric method (Jackson 1973)
Available potassium	110 kg/ha	Medium	Ammonium acetate method (Jackson 1973)
Available calcium	176.22 kg/ha		Ammonium acetate method (Jackson 1973)
Available magnesium	133.67 kg/ha		Ammonium acetate method (Jackson 1973)
Organic carbon	0.79%	High	Walkley and Black rapid titration method (Jackson 1973)
pH	5.2	Acidic	1:2 soil solution ratio using pH meter with glass electrode

3.1.3 Cropping history of the field

The experimental site selected was lying fallow for three months before the experiment and prior to that, it was under a bulk crop of sweet potato.

3.1.4 Season

The experiments were conducted during the period December 12, 1988 to February 1, 1989 (Summer season of 1989).

3.1.5 Weather conditions

The experimental site enjoys a tropical humid climate. Data on maximum temperature, minimum temperature, rainfall and relative humidity during the entire cropping period and the average value of the above parameters over 15 years were collected from the Meteorological Observatory at the College of Agriculture and is presented as weekly averages in Appendix I and II and Figure 1.

On comparison, it was revealed that, normal weather conditions prevailed during the crop growth period.

3.1.6 Seed materials

The seed material of all the three green manures ie Sesbania rostrata, Sesbania aculeata and Crotolaria juncea were obtained from the Tamil Nadu Agricultural University Farm, Coimbatore.

3.1.7 Fertilizer and soil amendment

For experiment II, superphosphate containing 16 per cent P_2O_5 was used as fertilizer and quick lime (neutralizing value 179) was used as a soil amendment. A mixed culture of Rhizobium (KAUS 5 and 6) obtained from the Department of Plant Pathology, College of Agriculture, Vellayani was used for inoculating Sesbania rostrata in

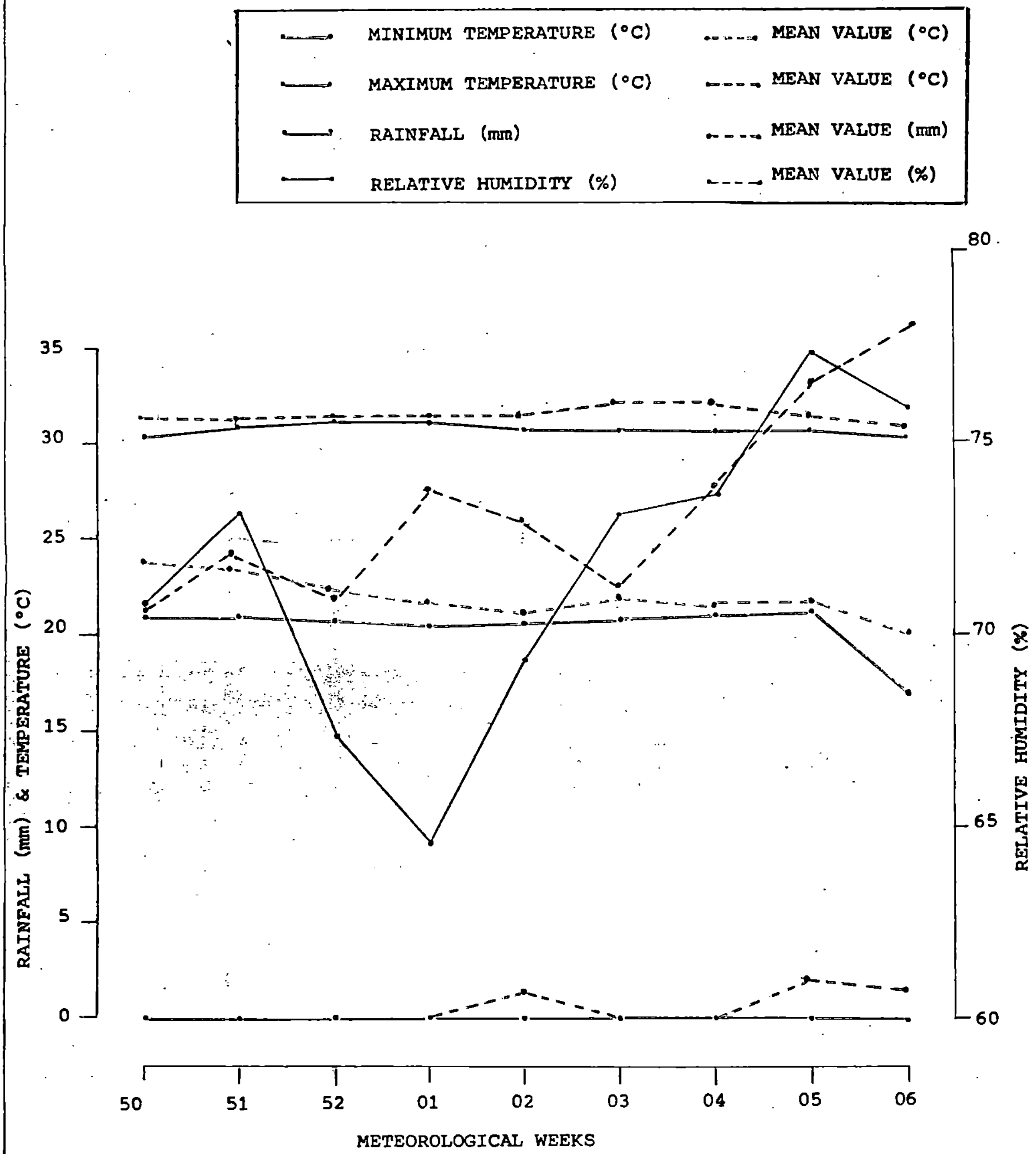

Fig 1. Weather data during the cropping period and the mean of 15 years.

Experiment II. No fertilizer, seed inoculation or soil amendment was used for Experiment I.

3.2 METHODS

3.2.1 Design and lay out

Both the experiments were laid out in Randomised Block Design with three replications. The procedure followed for the allocation of various treatments to different plots was in accordance with Yates (1937). The lay out plan of both the experiments is given in Figure 2. The details of the lay out are given below.

(A) Experiment I

Number of treatments combinations	= 12
Number of blocks	= 3
Number of replications	= 3
Plot size	= 12.8 m^2 (4 x 3.2 m)
Net plot size	= 3.5 x 2.7 m (9.45 m^2)
Total number of plots	= 36
Method of planting	= Broadcast

3.2.2 Treatments

Three green manures (Sesbania rostrata, Sesbania aculeata and Crotolaria juncea) and four days of harvest (30, 40, 50 and 60 DAS/50 per cent flowering state) were fixed as the treatments.

Green manures	s_1	- *Sesbania rostrata*
	s_2	- *Sesbania aculeata*
	s_3	- *Crotolaria juncea*
Days of harvest	h_1	- 30 DAS
	h_2	- 40 DAS
	h_3	- 50 DAS
	h_4	- 60 DAS/ flowering stage which ever was earlier.

3.2.3 Treatment combinations

The treatment combinations are as follows:

T_1	- s_1h_1	T_7	- s_2h_3
T_2	- s_1h_2	T_8	- s_2h_4
T_3	- s_1h_3	T_9	- s_3h_1
T_4	- s_1h_4	T_{10}	- s_3h_2
T_5	- s_2h_1	T_{11}	- s_3h_3
T_6	- s_2h_2	T_{12}	- s_3h_4

(B) Experiment II

Number of treatments	= 12
Number of blocks	= 3
Number of replications	= 3
Gross plot size	= 12.8 m^2 (4 x 3.2 m)
Net plot size	= 9.45 m^2 (3.5 x 2.7 m)
Total number of plots	= 36
Method of planting	= Broadcast
Green manure	= *Sesbania rostrata*

Key

Experiment I		Experiment II	
T_1	s_1h_1	T_1	$l_oi_op_o$
T_2	s_1h_2	T_2	$l_oi_op_1$
T_3	s_1h_3	T_3	$l_oi_1p_o$
T_4	s_1h_4	T_4	$l_oi_1p_1$
T_5	s_2h_1	T_5	$l_1i_op_o$
T_6	s_2h_2	T_6	$l_1i_op_1$
T_7	s_2h_3	T_7	$l_1i_1p_o$
T_8	s_2h_4	T_8	$l_1i_1p_1$
T_9	s_3h_1	T_9	$l_2i_op_o$
T_{10}	s_3h_2	T_{10}	$l_2i_op_1$
T_{11}	s_3h_3	T_{11}	$l_2i_1p_o$
T_{12}	s_3h_4	T_{12}	$l_2i_1p_1$

EXPERIMENT I

REPLICATION I

T_5	T_3	T_1
T_{12}	T_2	T_6
T_7	T_{10}	T_1
T_9	T_4	T_8

REPLICATION II

T_9	T_5	T_{11}
T_1	T_3	T_7
T_{12}	T_6	T_4
T_2	T_{10}	T_8

REPLICATION III

T_{12}	T_1	T_8
T_2	T_6	T_9
T_5	T_{10}	T_7
T_4	T_{11}	T_3

EXPERIMENT II

REPLICATION I

T_6	T_2	T_3
T_1	T_4	T_8
T_9	T_5	T_{11}
T_{10}	T_7	T_{12}

REPLICATION II

T_{12}	T_8	T_3
T_4	T_1	T_7
T_{11}	T_6	T_5
T_9	T_2	T_{10}

REPLICATION III

T_8	T_9	T_{10}
T_3	T_1	T_7
T_{12}	T_2	T_4
T_5	T_6	T_{11}

Fig 2. Layout plan of the experiments .

3.2.4 Treatments

Three levels of lime, two levels of phosphorus and two levels of inoculation were fixed as the treatments.

Lime (L)	l_0	-	0 kg/ha
	l_1	-	250 kg/ha
	l_2	-	500 kg/ha
Phosphorus (P)	p_0	-	0 kg/ha
	p_1	-	30 kg/ha
Inoculation (I)	i_0	-	No inoculation
	i_1	-	inoculation with <u>Rhizobium</u> culture (No. KAUS 5 and 6)

3.2.5 Treatment combinations

Treatment combinations are as follows.

T_1	- $l_0 i_0 p_0$	T_7	- $l_1 i_1 p_0$
T_2	- $l_0 i_0 p_1$	T_8	- $l_1 i_1 p_1$
T_3	- $l_0 i_1 p_0$	T_9	- $l_2 i_0 p_0$
T_4	- $l_0 i_1 p_1$	T_{10}	- $l_2 i_0 p_1$
T_5	- $l_1 i_0 p_0$	T_{11}	- $l_2 i_1 p_0$
T_6	- $l_1 i_0 p_1$	T_{12}	- $l_2 i_1 p_1$

3.2.6 Field culture

3.2.6.1 Land preparation

The experimental site were dug twice, weeds and stubbles removed, clods broken and the field was laid out with bunds of 40 cm width around. Individual plots were again dug and perfectly levelled. Seeds were uniformly broadcast in all the plots, in both the experiments.

3.2.6.2 Fertilizer application

No fertilizer or soil amendment (lime) was applied in Experiment I. Lime and phosphorus were applied to the plots in the form of calcium oxide and superphosphate in stipulated doses as per the treatment combinations for Experiment II. The entire dose of phosphorus was applied as basal, one day before sowing. Lime was applied to the plots, 14 days before sowing.

3.2.6.3 Seeds and sowing

Bold seeds were selected for sowing. For both the experiments the seeds were subjected to 24 hours soaking before sowing. In experiment II, the soaked seeds of *Sesbania rostrata* were inoculated with *Rhizobium* culture (as per the treatments) and then sown. The seed rate used for both the experiments was 30 kg/ha. The seeds were broadcast uniformly in all the plots. The plots were irrigated immediately after sowing.

3.2.6.4 Maintenance of the crop

In both the experiments, irrigation was given daily, upto five days after sowing. Thereafter, irrigation was given once a week, upto thirty five days after sowing. In both the experiments a uniform population of 300 plants per plot was maintained in all the plots, 15 days after sowing. One hand weeding was done in all plots, in both experiments at twenty days after sowing. In experiment II, the *Sesbania rostrata* plants were sprayed with *Rhizobium* suspension at 20 DAS in plots, where seed inoculation was carried out.

3.2.6.5 Plant protection

No pests and diseases were observed in both the experiments. Hence, no plant protection operations were carried out during the cropping period.

3.2.6.6 Harvest

In experiment I, the plants were harvested at 30, 40 and 50 days after sowing. Since, 50 per cent flowering of the three green manure crops was observed at 50 days after sowing, the final harvest was done at this time. Hence the 60 day treatment has been deleted from analysis.

In experiment II, *Sesbania rostrata* was harvested only once, at 50 days after sowing (50 per cent flowering time).

Observations

3.2.7 Growth characters

3.2.7.1 Height of the plants

In experiment I, the height of the three green manure crops was taken at 30, 40 and 50 days after sowing (date of final harvest). In experiment II, the height of the plants was taken only once, at the time of final harvest (ie 50 DAS). In both experiments, observations were taken from ten plants selected at random, after eliminating border plants. The height of the plants was measured from the base to the growing tip. From the data obtained, the mean height of the plants was calculated and expressed in centimetres.

3.2.7.2 Number of root nodules

In Experiment I, this parameter was studied at 30, 40 and 50 days after sowing (final harvest). In Experiment II, this parameter was studied only at final harvest (50 DAS). Five plants were randomly selected from each plot, carefully uprooted and the roots were washed carefully with water. The root nodule number was counted and expressed as mean value.

3.2.7.3 Number of stem nodules

This parameter was studied for experiment II only. Five plants were randomly selected and their stem nodules were counted and expressed as mean value.

3.2.7.4 Root and stem nodule dry weight

After counting the stem and root nodules were separated carefully and dried in a hot air oven at 70°C for eight hours, weighed and expressed as g/plant.

3.2.8 Yield

3.2.8.1 Green matter yield

This parameter was determined at 30, 40 and 50 days after sowing in Experiment I and at 50 days after sowing in Experiment II. The entire plants from the net plot area was selected from each plot and their fresh weight, excluding the roots was determined. From the green matter yield/plot, the green matter yield per hectare was computed and expressed as t/ha.

3.2.8.2 Dry matter yield

This parameter was determined at 30, 40 and 50 DAS in Experiment I and at 50 DAS in Experiment II. Thirty plants were chosen from those used for determining green matter production, cut into small bits, sun dried and then oven dried in a hot air oven at 70°C, till constant weights were obtained. Dry matter yield was computed as per the procedure adopted for determining the green matter yield and it was expressed as t/ha.

3.2.9 Chemical analysis

3.2.9.1 Plant analysis

The whole plant was analysed for nitrogen, phosphorus, potassium, calcium and magnesium contents at 30, 40 and 50 DAS in Experiment I and at 50 DAS in Experiment II. The plant samples collected from each plot at the time of harvest (s) in both the experiments were dried to constant weights in an electric hot air oven at 70^{o}C, ground and passed through a 0.5 mm mesh in a Willey mill. The required quantity of samples were then weighed out accurately in an electronic balance, subjected to acid extraction and the nutrient contents determined and expressed as percentages on dry weight basis. The root and stem nodules were also analysed separately for their nitrogen contents.

3.2.9.1.1 Total nitrogen content

Total nitrogen content in plant and root and stem nodules were estimated by modified microkjeldahl method as given by Jackson (1973).

3.2.9.1.2 Total phosphorus content

Phosphorus content was estimated colorimetrically by Vanado-molybdo-phosphoric yellow color method (Jackson, 1973) and read in Spectronic 2000.

3.2.9.1.3 Total potassium content

Total potassium content in plant was estimated by atomic absorption spectrophotometry after wet digestion of the sample using di-acid mixture as suggested by Perkin-Elmer Corporation,(1982).

3.2.9.1.4 Total calcium content

Total calcium content in plant was estimated by atomic absorption spectrophotometry after wet digestion of the sample using di-acid mixture, as suggested by Perkin-Elmer Corporation,(1982).

3.2.9.1.5 Total magnesium content

This was determined by atomic absorption spectrophotometry after wet digestion of the sample using di-acid mixture as suggested by Perkin-Elmer Corporation,(1982).

3.2.9.2 Uptake of nutrients

The total uptake of nitrogen, phosphorus and potassium, calcium and magnesium at harvest(s) in both experiments were calculated the product of the content of these nutrients in the plant samples and the respective dry weights and expressed as kg/ha.

3.2.9.3 Rhizobium population in the rhizophere

This parameter was estimated by soil dilution and plating method in yeast extract mannitol agar with congo red medium as suggested by Vincent (1970) and expressed as 10^4/g soil.

3.2.9.4 Soil analysis

Soil samples were taken from the experimental area, before and after the experiments. The soil samples were dried and analysed for the various parameters as per the methods given in Table 1.

3.2.10 Economics of cultivation

The economics of cultivation in Experiment II was worked out based on the various input costs.

Net income (Rs./ha) = Gross income - Cost of cultivation

$$\text{Cost-benefit ratio} = \frac{\text{Gross income}}{\text{Cost of cultivation}}$$

3.2.11 Statistical analysis

The data relating to each character in both the experiments were analysed using the analysis of variance technique as applied to randomised block design described by Cochran and Cox (1965). When the effects were found to be significant critical difference was calculated for effecting multiple comparisons among the means.

The data were analysed using a Keltron Versa IWS computer system.

RESULTS

RESULTS

EXPERIMENT I

The results of the investigations on the biomass productivity and nutrient accumulation of Sesbania rostrata in comparison with other green manures are given below.

4.1 Height of plants

The mean data on the height of plants are presented in Table 2.

Time of harvest significantly increased the plant height. There was a progressive increase in the height of plant when the time of harvest was delayed from 30 DAS to 50 DAS.

There was significant difference in plant height with the types of legume also. Among the different green manure crops tried, Crotolaria juncea recorded the maximum plant height followed by Sesbania aculeata and Sesbania rostrata. Sesbania rostrata was significantly inferior to the other two legumes with respect to plant height.

Interaction effect between time of harvest and types of legume was also significant.

4.2 Total green matter production

The mean data on the total green matter production are presented in Table 2 and Figure 3.

Time of harvest exerted significant influence on the total green matter produced. There was significant increase in green matter production with the successive increase in number of days taken for harvest from 30 DAS to 50 DAS.

The total green matter produced differed significantly with the type of legumes. *Sesbania rostrata* was significantly inferior to the other two legumes tried. The same trend in plant height was noted in green matter yield also. *Crotolaria juncea* produced maximum growth followed by *Sesbania aculeata* and *Sesbania rostrata*.

The interaction effect between times of harvest and type of legume was marked in the total green matter yield. *Crotolaria juncea* harvested at 50 DAS, proved to be superior both to *Sesbania aculeata* and *Sesbania rostrata* harvested at 50 DAS in terms of green matter production.

Table 2. Growth characteristics of the green manures

	Height of plants (cm)	Total green matter produ-ced (t/ha)	Total dry matter produ-ced (t/ha)	Root nodule (no/ plant)	Dry weight of root nodule (g/plant)
Harvest					
h_1	50.67	5.14	1.44	20.97	0.054
h_2	89.62	9.17	3.21	32.18	0.123
h_3	122.36	13.40	4.61	40.92	0.246
F(2,16)	881.40**	2274.71**	1574.97**	308.81**	342.95**
SEm ±	1.209	0.086	0.400	0.569	0.005
CD(0.05)	3.624	0.260	0.120	1.706	0.015
Green manures					
s_1	74.21	8.61	2.77	36.12	0.152
s_2	79.72	9.13	3.07	40.70	0.209
s_3	108.71	9.98	3.40	17.26	0.073
F(2,16)	234.99**	63.48**	61.41**	476.21**	175.04**
SEm ±	1.209	0.086	0.400	0.569	0.005
CD(0.05)	3.624	0.260	0.120	1.706	0.015
Harvest x greenmanures					
h_1s_1	44.80	04.96	1.39	27.00	0.060
h_1s_2	46.27	05.03	1.40	27.00	0.091
h_1s_3	60.93	05.14	1.52	08.90	0.023
h_2s_1	70.00	08.94	3.12	37.02	0.137
h_2s_2	87.03	09.06	3.17	43.55	0.201
h_2s_3	108.83	09.52	3.33	16.00	0.040
h_3s_1	104.83	11.94	3.82	44.33	0.273
h_3s_2	105.87	13.29	4.65	51.55	0.329
h_3s_3	155.37	14.98	5.36	26.88	0.142
F(4,16)	27.71**	23.45**	33.21**	12.38**	12.38**
SEm ±	2.094	0.150	0.069	0.986	0.009
CD(0.05)	6.278	0.450	0.208	2.956	0.027

HARVEST
h_1 - 30 DAS
h_2 - 40 DAS
h_3 - 50 DAS

GREEN MANURES
s_1 - Sesbania rostrata
s_2 - Sesbania aculeata
s_3 - Crotolaria juncea

** Significant at 1% level
* Significant at 5% level

4.3 Total dry matter produced

The mean data on the total dry matter production are given in Table 2 and Figure 3.

The total dry matter production was significantly influenced by the time of harvest. There was significant increase in total dry matter production with an increase in time of harvest from 30 DAS to 50 DAS.

The effect of type of legume was also significant and Crotolaria juncea was significantly superior to Sesbania aculeata and Sesbania rostrata.

Interaction effect between time of harvest and types of legumes was also significant. Crotolaria juncea at 50 DAS recorded the maximum value for this parameter, followed by Sesbania aculeata. Sesbania rostrata recorded the lowest dry matter production at harvest (50 DAS).

4.4 Number of root nodules/plant

The mean data on the number of root nodules/plant are presented in Table 2 and Figure 5.

Time of harvest significantly influenced the total number of root nodules produced per plant. There was a progressive increase in the number of root nodules/plant when the time of harvest was delayed upto 50 DAS.

The effects due to different types of legumes on the production of root nodules/plant were statistically significant. Sesbania aculeata produced the maximum number of root nodules and it was superior to both Sesbania rostrata and Crotolaria juncea. However, Sesbania rostrata was significantly superior to Crotolaria juncea with respect to the production of total number of root nodules per plant.

Interaction between times of harvest and types of legumes was also found to be significant.

4.5 Dry weight of root nodules/plant

The mean data on the dry weight of root nodules/plant are given in Table 2 and Figure 5.

Dry weight of root nodules per plant was significantly influenced by the time of harvest. The increase in dry weight of nodule/plant with increase in time of harvest was progressive and the maximum dry weight was obtained at 50 DAS.

There was significant difference in the total dry weight of root nodules produced per plant with the type of legume. The maximum dry weight of root nodules was obtained for Sesbania aculeata, and it was statistically superior to the other two legumes tried. However, Sesbania rostrata was significantly superior to Crotolaria juncea.

The interaction effect between time of harvest and type of legumes was also significant.

4.6 Analysis of plant samples

4.6.1 Nitrogen content of root nodules

The mean data on the nitrogen content of root nodules are presented in Table 3.

Time of harvest exerted significant influence on the nitrogen content of root nodule. There was progressive increase in this parameter as the days of harvest were delayed from 30 to 50 DAS. The maximum nitrogen content was obtained when the legumes were harvested at 30 DAS.

Nitrogen content of root nodules was also influenced by the type of legumes. Sesbania aculeata recorded the highest value for root nodule nitrogen and it was significantly superior to that of Sesbania rostrata. However, the differences in nitrogen content of root nodules of Sesbania aculeata and Crotolaria juncea were on par.

The interaction effect between time of harvest and types of legume was also statistically significant.

Table 3. Nutrient content of the green manures

	Nitrogen content of root nodue (%)	Nitrogen content of plants (%)	Phosphorus content of plants (%)	Potassium content of plants (%)	Calcium content of plants (%)	Magnesium content of plants (%)
Harvest						
h_1	0.49	2.39	0.31	1.36	0.69	0.22
h_2	0.76	2.19	0.40	1.42	0.81	0.26
h_3	1.20	1.97	0.52	1.55	0.88	0.31
F(2,16)	300.25**	31.68**	87.19**	74.22**	51.53**	6.17*
SEm ±	0.020	0.037	0.011	0.014	0.013	0.019
CD(0.05)	0.062	0.111	0.034	0.034	0.040	0.057
Green Manures						
s_1	0.59	2.18	0.41	1.44	0.87	0.20
s_2	0.94	2.22	0.36	1.54	0.85	0.20
s_3	0.92	2.15	0.46	1.34	0.66	0.39
F(2,16)	88.85**	0.82	21.75**	77.67**	74.46**	25.92**
SEm ±	0.020	0.037	0.011	0.014	0.013	0.019
CD(0.05)	0.062	0.111	0.034	0.034	0.040	0.057
Harvest x Green manures						
h_1s_1	0.26	2.34	0.28	1.37	0.79	0.20
h_1s_2	0.69	2.46	0.26	1.46	0.74	0.18
h_1s_3	0.54	2.36	0.38	1.24	0.54	0.28
h_2s_1	0.50	2.20	0.41	1.44	0.88	0.20
h_2s_2	0.89	2.21	0.35	1.50	0.88	0.17
h_2s_3	0.90	2.16	0.44	1.32	0.68	0.41
h_3s_1	1.03	1.99	0.53	1.52	0.95	0.27
h_3s_2	1.25	1.99	0.46	1.66	0.93	0.24
h_3s_3	1.32	1.94	0.56	1.46	0.76	0.44
F(4,16)	4.037	NS	NS	NS	NS	NS
SEm ±	0.035	0.064	0.019	0.019	0.023	0.033
CD(0.05)	0.107	-	-	-	-	-

HARVEST
h_1 - 30 DAS
h_2 - 40 DAS
h_3 - 50 DAS

GREEN MANURES
s_1 - *Sesbania rostrata*
s_2 - *Sesbania aculeata*
s_3 - *Crotolaria juncea*

** Significant at 1% level
* Significant at 5% level
NS Not significant

4.6.2 Nitrogen content of plants

The mean data on the nitrogen content of plants are presented in Table 3.

Nitrogen content of plant was significantly influenced by the times of harvest. There was significant reduction in total nitrogen content of plants when the time of harvest was delayed from 30 DAS to 50 DAS.

The effects due to different legumes on the total nitrogen content was not statistically significant. However, the maximum value was obtained for *Sesbania aculeata*, followed by *Sesbania rostrata*. *Crotolaria juncea* recorded the least value. Interaction effect was not significant.

4.6.3 Phosphorus content of plants

The mean data on the total phosphorus content of plants are presented in Table 3.

Time of harvest had significant influence on the total phosphorus content of plants. The total phosphorus content increased progressively when time of harvest was increased upto 50 DAS

The influence of different legumes was also found to be significant on this aspect. Crotolaria juncea had the maximum phosphorus content and it was significantly superior to the other two legumes. However, the phosphorus content in Sesbania rostrata was statistically superior to Sesbania aculeata. Interaction effects were not significant.

4.6.4 Potassium content of plants

The mean data on the total potassium content of plants are presented in Table 3.

Time of harvest exerted profound influence on the total potassium content of plants. Delay in harvest from 30 to 50 DAS significantly influenced this parameter and the highest value was obtained when the plants were harvested at 50 DAS.

The effect due to different legumes was also found to be significant. Sesbania aculeata recorded maximum potassium content and it was significantly superior to Sesbania rostrata and Crotolaria juncea. Sesbania rostrata in turn was superior to Crotolaria juncea with regard to this parameter.

Interaction effects were not significant.

4.6.5 Calcium content of plants

The mean data on the total calcium content of plants are presented in Table 3.

The effect due to times of harvest on this parameter was statistically significant. Calcium content of plants was maximum when the legumes were harvested at 50 DAS.

The effect due to different legumes was also found to be statistically significant. *Sesbania rostrata* was superior to both *Sesbania aculeata* and *Crotolaria juncea* in their total calcium content. *Crotolaria juncea* recorded the minimum calcium content. Interaction effects were not significant.

4.6.6 Magnesium content of plants

The mean data on the total magnesium content of plants are presented in Table 3.

The total magnesium content of plant was significantly influenced by the times of harvest. Harvesting at 50 DAS had maximum magnesium content and it was superior to early harvests. However, the difference in magnesium content due to harvest at 30 and 40 DAS were statistically not significant.

The total magnesium content was also significantly influenced by the type of legume. The maximum magnesium content was observed for Crotolaria juncea and it was superior to the other two green manures. The magnesium content of Sesbania rostrata was higher than that of Sesbania aculeata though they were on par.

4.7 Nutrient uptake by plants

4.7.1 Total uptake of nitrogen by plants

The mean data on the total uptake of nitrogen by plants are given in Table 4 and in Figure 4.

Times of harvest significantly increased the uptake of nitrogen by green manures. There was progressive increase in the nitrogen uptake when the time of harvest was delayed.

Type of green manure also significantly influenced the total uptake of nitrogen by plants. Crotolaria juncea recorded the maximum uptake of nitrogen and it was superior to the other two green manures. The nitrogen uptake by Sesbania rostrata was significantly inferior to both Crotolaria juncea and Sesbania aculeata.

The interaction between time of harvest and type of green manure was also found to be significant. Crotolaria juncea at 50 DAS recorded the highest uptake of nitrogen, followed by Sesbania aculeata, Sesbania rostrata at 50 DAS recorded the lowest value for this parameter.

4.7.2 Total uptake of phosphorus by plants

The mean data on the total uptake of phosphorus by green manure are given in Table 4 and in Figure 4.

Time of harvest exerted significant influence on the total uptake of phosphorus by plants. The uptake increased progressively when harvesting was delayed upto 50 DAS.

The effect due to different legumes was also statistically significant. Crotolaria juncea was superior to the other two legumes in the phosphorus uptake. Sesbania rostrata and Sesbania aculeata were on par, eventhough the former recorded a higher value.

4.7.3. Total uptake of potassium by plants

The mean data on the total uptake of potassium by green manures are presented in Table 4 and in Figure 4.

The total uptake of potassium by plants significantly increased with increase in number of days taken for harvest. The maximum total uptake of potassium was obtained when plants were harvested at 50 DAS.

The effects due to the types of green manures was also significant. Sesbania aculeata recorded the maximum uptake of potassium and it was significantly superior to

Table 4. Nutrient uptake by the green manures

	Nitrogen uptake (kg/ha)	Phosphorus uptake (kg/ha)	Potassium uptake (kg/ha)	Calcium uptake (kg/ha)	Magnesium uptake (kg/ha)
Harvest					
h_1	34.35	4.40	19.42	9.85	3.26
h_2	70.14	12.87	45.66	25.99	8.52
h_3	90.13	23.88	71.37	40.13	14.93
F(2,16)	410.655**	473.914**	2170.622**	1268.99**	49.01**
SEm ±	1.394	0.474	0.557	0.425	0.835
CD(0.05)	4.180	1.422	1.671	1.275	2.503
Green manures					
s_1	55.87	12.35	40.69	24.91	6.42
s_2	65.22	12.02	48.45	27.17	6.45
s_3	70.54	16.79	47.30	23.88	13.85
F(2,16)	17.57**	31.47**	56.51**	15.60**	26.25**
SEm ±	1.394	0.474	0.557	0.425	0.835
CD(0.05)	4.180	1.422	1.671	1.275	2.503
Harvest x Green manures					
h_1s_1	32.51	3.79	18.99	10.95	2.71
h_1s_2	34.57	3.64	20.50	10.39	2.81
h_1s_3	35.98	5.76	18.78	8.20	4.25
h_2s_1	68.49	12.89	45.05	27.37	6.37
h_2s_2	70.07	11.95	47.56	27.88	5.47
h_2s_3	71.87	14.52	44.36	22.72	13.73
h_3s_1	75.60	20.36	58.02	36.39	10.18
h_3s_2	91.02	21.21	77.30	43.24	11.06
h_3s_3	103.78	30.07	78.78	40.74	23.57
F(4,16)	8.78**	8.76**	45.67**	12.67**	5.32**
SEm ±	2.415	0.822	0.966	0.737	1.446
CD(0.05)	7.241	2.463	2.895	2.208	4.337

HARVEST
h_1 - 30 DAS
h_2 - 40 DAS
h_3 - 50 DAS

GREEN MANURES
s_1 - *Sesbania rostrata*
s_2 - *Sesbania aculeata*
s_3 - *Crotolaria juncea*

** Significant at 1% level
* Significant at 5% level

cally not significant in this respect. _Sesbania rostrata_ was found to be significantly inferior to the other two legumes in its total uptake of potassium.

4.7.4 Total uptake of calcium by plants

The mean data on the total uptake of calcium by plants are presented in Table 4.

Time of harvest exerted profound influence on the total uptake of calcium by plants. The effects due to harvest at different times were statistically significant and harvesting at 50 DAS was significantly superior to earlier harvests.

The total uptake of calcium was significantly influenced by the type of green manure. _Sesbania aculeata_ was significantly superior to both _Sesbania rostrata_ and _Crotolaria juncea_. The difference in effect due to _Sesbania rostrata_ and _Crotolaria juncea_ was statistically not significant, even though _Sesbania rostrata_ showed a higher rate of uptake of calcium.

The interaction effect was also found to be significant.

4.7.5 Total uptake of magnesium by plants

The mean data on the total uptake of magnesium by plants are presented in Table 4.

The effect due to time of harvest was significant on the total uptake of magnesium by green manures. There was a progressive increase in the total uptake of magnesium as the time of harvest was delayed from 30 DAS to 50 DAS.

The type of green manure also significantly influenced this parameter. Crotolaria juncea was significantly superior to both Sesbania rostrata and Sesbania aculeata. The effects due to the two spp. of Sesbania were statistically on par. The interaction effect was also significant.

4.8 Soil nutrient status after the experiment

The mean data on the available nutrient status of the soil after the experiment are presented in Table 5.

Time of harvest significantly influenced the available nitrogen content of the soil after the experiment. The available nitrogen status was increased as the time of harvest was delayed. However, the effect due to time of harvest on the available nutrient status of the soil after the experiment was not significant with respect to

Table 5. Available nutrient status, organic carbon and pH of the soil after the experiment

	Soil available nitrogen (kg/ha)	Soil available phosphorus(kg/ha)	Soil available potassium(kg/ha)	Soil available calcium (kg/ha)	Soil available magnesium(kg/ha)	Soil organic carbon (%)	Soil pH
Harvest							
h_1	193.78	21.18	109.29	176.33	134.00	0.80	5.28
h_2	237.56	21.39	109.07	176.11	135.88	0.80	5.28
h_3	273.44	21.23	109.12	176.11	134.00	0.80	5.27
F(2,16)	87.346**	NS	NS	NS	NS	NS	NS
SEm ±	4.269	0.685	0.762	3.459	2.834	0.0055	0.0093
CD(0.05)	12.79	-	-	-	-	-	-
Green manures							
s_1	233.78	21.20	109.37	176.22	134.00	0.80	5.30
s_2	235.78	21.36	109.08	176.11	133.67	0.80	5.20
s_3	235.22	21.23	109.03	176.22	136.22	0.80	5.30
F(2,16)	NS	NS	NS	NS	NS	NS	23.03**
SEm ±	4.269	0.685	0.762	3.459	2.834	0.0055	0.0093
CD(0.05)	-	-	-	-	-	-	0.028
Harvest x Green manures							
h_1s_1	195.00	21.05	110.07	176.33	131.33	0.80	5.30
h_1s_2	195.66	21.10	108.99	176.33	135.00	0.81	5.23
h_1s_3	190.66	21.39	108.82	176.33	135.67	0.80	5.30
h_2s_1	237.33	21.51	108.60	176.66	135.67	0.79	5.30
h_2s_2	236.00	21.61	109.36	176.33	134.67	0.80	5.23
h_2s_3	239.33	21.05	109.26	175.33	137.33	0.79	5.30
h_3s_1	269.00	21.06	109.47	175.67	135.00	0.80	5.30
h_3s_2	275.67	21.35	108.91	175.67	131.33	0.80	5.20
h_3s_3	275.67	21.25	109.00	177.00	135.67	0.80	5.30
F(4,16)	NS	NS	NS	NS	NS	NS	NS
SEm ±	7.394	1.186	1.319	5.992	4.909	0.0096	0.0162
CD(0.05)	-	-	-	-	-	-	-

HARVEST

h_1 - 30 DAS
h_2 - 40 DAS
h_3 - 50 DAS

GREEN MANURES

s_1 - *Sesbania rostrata*
s_2 - *Sesbania aculeata*
s_3 - *Crotolaria juncea*

** Significant at 1% level
* Significant at 5% level
NS - Not significant

either phosphorus, potassium, calcium or magnesium.

The type of green manure did not exert any significant influence on the available nutrient status of the soil. Interaction effect too did not influence this parameter.

4.9 Soil organic carbon

The mean data on the soil organic carbon after the experiment are presented in Table 5.

Neither time of harvest nor type of green manure exert any significant influence on the soil organic carbon content. Interaction effect too was not significant.

4.10 Soil pH

The mean data on the soil pH after the experiment are presented in Table 5.

The differences in soil pH due to different times of harvest was statistically not significant.

The type of green manure was found to exert significant influence on the soil pH. The pH value obtained for Sesbania rostrata and Crotolaria juncea was the same (5.3) and it was significantly higher to that obtained with Sesbania aculeata (5.2)

Interaction effect was not significant.

EXPERIMENT II

The results on the effect of *Rhizobium* inoculation, liming and phosphorus application on *Sesbania rostrata* are given below.

4.1 Growth characters

4.1.1 Height of plants

The data on the mean height of plants as affected by the treatments are presented in Table 6.

The data revealed that liming had significant effect on the height of plant. Increasing levels of lime increased plant height, with l_2 recording the maximum plant height followed by l_1.

Inoculation levels had no significant influence on plant height. Phosphorus application had significant effect on plant height, with p_1 recording higher value than p_0.

The interactions LI, LP and IP had no significant influence on this growth character.

4.1.2 Total green matter production

The mean data on the total green matter production are presented in Table 6 and in Figure 6.

Table 6. Effect of Rhizobium inoculation, liming and phosphorus application on the growth characteristics of *Sesbania rostrata*

	Plant height (cm)	Total green matter prodn. (t/ha)	Total dry matter prodn. (t/ha)	Root nodule (No./plant)	Stem nodule (No./plant)
l_0	106.34	12.09	3.85	47.18	16.44
l_1	127.88	16.27	5.18	67.47	27.12
l_2	168.23	18.72	6.05	72.85	36.41
F(2,22)	9519.70**	6034.61**	9931.76**	71.828**	136.00**
SEm ±	0.456	0.611	0.016	2.261	1.211
CD(0.05)	0.945	0.126	0.033	4.689	2.513
i_1	201.02	23.35	7.49	84.49	23.84
i_2	201.44	23.73	7.59	102.99	56.13
F(1.22)	NS	25.80**	28.43**	44.65**	473.21**
SEm ±	0.372	0.049	0.013	1.846	0.989
CD(0.05)	-	0.103	0.027	3.830	2.052
p_0	132.75	15.53	4.98	61.53	26.24
p_1	135.56	15.85	5.08	63.46	27.08
F(1,22)	57.46**	39.809**	53.55**	NS	NS
SEm ±	0.372	0.049	0.013	1.846	0.989
CD(0.05)	0.771	0.103	0.027	-	-
l_0i_0	106.53	11.96	3.82	39.60	7.40
l_0i_1	106.15	12.21	3.89	54.72	25.48
l_1i_0	127.62	16.10	5.13	64.16	19.23
l_1i_1	128.15	16.43	5.23	70.78	35.00
l_2i_0	167.88	18.63	6.04	65.21	21.05
l_2i_1	168.58	18.81	6.07	80.49	51.78
F(2,22)	NS	NS	NS	2.400*	22.067**
SEm ±	0.644	0.086	0.022	3.197	1.713
CD(0.05)	-	-	-	6.632	3.554
l_0p_0	105.47	11.91	3.79	44.67	16.38
l_0p_1	107.22	12.26	3.92	49.65	16.50
l_1p_0	126.22	16.11	5.12	67.49	26.68
l_1p_1	129.55	16.43	5.24	67.44	27.56
l_2p_0	166.55	18.59	6.04	73.28	35.67
l_2p_1	169.92	18.85	6.07	72.85	37.16
F(2,22)	NS	2.262*	4.944*	NS	NS
SEm ±	0.644	0.086	0.022	3.197	1.713
CD(0.05)	-	0.179	0.046	-	-
i_0p_0	132.78	15.39	4.94	55.44	14.34
i_0p_1	135.25	15.74	5.05	57.21	17.45
i_1p_0	132.71	15.68	5.03	67.62	38.14
i_1p_1	135.88	15.95	5.10	69.70	36.70
F(1,22)	NS	NS	NS	NS	5.285**
SEm ±	0.529	0.071	0.018	2.610	1.399
CD(0.05)	-	-	-	-	2.902

** Significant at 1% level NS – Not significant
* Significant at 5% level

The data showed that liming had significant influence on total green matter production with l_2 recording the maximum value, followed by l_1. Treatment l_0 recorded the lowest value for total green matter production.

Inoculation significantly influenced this parameter with i_1 recording a higher value than i_0.

Phosphorus application also significantly influenced total green matter production with p_1 recording a higher value than p_0.

The interactions LI and IP had no significant influence on total green matter production. LP had significantly influenced this parameter with l_2p_1 recording the maximum value.

4.1.3 Total dry matter production

The data on total dry matter production are presented in Table 6 and in Figure 6.

Total dry matter production was significantly influenced by liming. Increasing levels of lime increased this parameter with l_2 recording maximum value, followed by l_1. Treatment l_0 recorded the least value for this parameter.

Inoculation significantly influenced total dry matter production with i_1 recording a higher value than i_0.

Phosphorus application significantly influenced total dry matter production with p_1 recording a higher value than p_0.

Among the interactions only LP significantly influenced, this parameter with l_2p_1 recording the maximum value and it was on par with l_2p_0.

4.1.4 Number of root nodules

The data on the mean number of root nodules are presented in Table 6 and in Figure 7.

This parameter was also significantly influenced by liming. Increasing levels of lime increased this parameter with l_2 recording the maximum value followed by l_1. Treatment l_0 recorded the lowest value.

Inoculation significantly increased the number of nodules per plant with i_1 recording a higher value than no inoculation (i_0).

Phosphorus application did not significantly influence this parameter.

Among the interactions only LI influenced the number of root nodules with l_2i_1 recording the maximum number.

4.1.5. Number of stem nodules

The data on the mean number of stem nodules are given in Table 6 and in Figure 7.

With regard to the number of stem nodules, there was significant difference among lime levels with l_2 recording the highest value followed by l_1. Inoculation significantly influenced this parameter with i_1 recording a higher value than i_0.

Phosphorus application had no significant influence on the number of stem nodules. Among the interactions, only LI and IP significantly influenced the number of stem nodules per plant, with l_2i_1 and i_1p_0 recording the maximum values, respectively.

4.1.6 Dry weight of root nodules

The data on the dry weight of root nodules per plant are presented in Table 7 and in Figure 7.

The data revealed that liming had significant influence on the dry weight of root nodules with l_2 recording the maximum value followed by l_1.

Inoculation significantly influenced the dry weight of root nodules with i_1 recording a higher value than i_0.

Phosphorus application had significant influence on this parameter with p_1 recording a higher value than p_0.

Table 7. Effect of *Rhizobium* inoculation, liming and phosphorus application on the nodule characteristics of *Sesbania rostrata*.

	Dry weight of root nodules (g/plant)	Dry weight of stem nodules (g/plant)	Nitrogen content of root nodules (%)	Nitrogen content of stem nodules (%)
l_0	0.442	0.093	1.18	1.29
l_1	0.581	0.167	1.41	1.32
l_2	0.643	0.279	1.42	1.45
F(2,22)	100.39**	220.51**	301.39**	33.26**
SEm ±	0.015	0.0087	0.014	0.008
CD(0.05)	0.031	0.0181	0.029	0.017
i_0	0.773	0.122	1.88	1.83
i_1	0.890	0.409	2.07	2.23
F(1,22)	44.42**	666.190**	127.18**	245.04**
SEm ±	0.012	0.0072	0.011	0.017
CD(0.05)	0.025	0.015	0.024	0.035
P_0	0.540	0.171	1.30	1.35
P_1	0.578	0.189	1.33	1.35
F(1,22)	5.74*	NS	5.45*	NS
SEm ±	0.012	0.0072	0.011	0.017
CD(0.05)	0.025	-	0.024	-
l_0i_0	0.403	0.031	1.00	1.21
l_0i_1	0.481	0.156	1.24	1.36
l_1i_0	0.580	0.100	1.35	1.22
l_1i_1	0.591	0.223	1.44	1.42
l_2i_0	0.573	0.114	1.40	1.22
l_2i_1	0.729	0.449	1.47	1.69
F(2,22)	11.421**	94.55**	26.041**	27.36**
SEm ±	0.021	0.012	0.019	0.029
CD(0.05)	0.044	0.026	0.041	0.061
l_0P_0	0.410	0.101	1.14	1.30
l_0P_1	0.470	0.090	1.09	1.28
l_1P_0	0.581	0.166	1.40	1.32
l_1P_1	0.582	0.167	1.42	1.32
l_2P_0	0.643	0.278	1.37	1.43
l_2P_1	0.656	0.289	1.48	1.46
F(2,22)	NS	NS	16.03**	NS
SEm ±	0.021	0.012	0.019	0.029
CD(0.05)	-	-	0.041	-
i_0P_0	0.501	0.081	1.26	1.23
i_0P_1	0.520	0.090	1.25	1.21
i_1P_0	0.581	0.278	1.35	1.47
i_1P_1	0.620	0.267	1.41	1.50
F(1,22)	NS	NS	9.67**	NS
SEm ±	0.017	0.010	0.016	0.024
CD(0.05)	-	-	0.034	-

* Significant at 5% level   NS - Not significant

** Significant at 1% level

Among the interactions only LI significantly influenced the dry weight of root nodules with l_2i_1 recording the highest value.

4.1.7 Dry weight of stem nodules

The data on the dry weight of stem nodules are presented in Table 7 and in Figure 7.

The dry weight of stem nodules per plant increased with increase in levels of lime upto l_2.

Inoculation significantly influenced this parameter with i_1 recording a higher value than i_0.

Phosphorus application had no significant influence on the dry weight of stem nodules.

Among the interactions, only LI was found to have a significant influence on this parameter with l_2i_1 recording the maximum value

4.2 Analysis of plant samples

4.2.1 Nitrogen content of root nodules

The data on the nitrogen content of root nodules are given in Table 7.

Nitrogen content of the root nodules increased significantly with increasing levels of lime application and the highest nitrogen content was observed at l_2. But l_2 and l_1 were on par.

Nitrogen content of root nodules increased significantly with inoculation, with i_1 recording a higher value than i_0.

Phosphorus application significantly influenced this parameter with p_1 recording a higher value than p_0.

All the interaction effects were significant. The maximum values were recorded by l_2i_1, l_2p_1 and i_1p_1.

4.2.2 Nitrogen content of stem nodules

The data on the nitrogen content of stem nodules are presented in Table 7.

Nitrogen content of stem nodules increased significantly with lime application. The highest nitrogen content was observed at l_2 level, followed by l_1.

Inoculation significantly influenced the nitrogen content of stem nodules with i_1 being superior to i_0.

Phosphorus application had no significant influence on the nitrogen content of stem nodules.

Among the interactions only LI had significant influence on this parameter with l_2i_1 recording the highest value.

4.2.3 Total nitrogen content of plant

The data on the total nitrogen content of plant are given in Table 8.

Liming had significant influence on the total nitrogen content of plant. As the levels of lime increased from l_0 to l_2, the total nitrogen content of plant also increased significantly.

Inoculation significantly increased the total nitrogen content of plant with i_1 recording a higher value than i_0.

Phosphorus application also significantly influenced the nitrogen content of plant with p_1 recording a higher value than p_0.

All the interactions were found to have a significant influence on this parameter with l_2i_1, l_2p_i and i_1p_i recording maximum values.

4.2.4 Total phosphorus content of plant

The data on the total phosphorus content of the plant are presented in Table 8.

Lime application significantly influenced the total phosphorus content of the plant. As liming levels increased from l_0 to l_2, the total phosphorus content of plant also increased.

Table 8. Effect of *Rhizobium* inoculation, liming and phosphorus application on the plant nutrient content of *Sesbania rotrata*

	Nitrogen content (%)	Phosphorus content (%)	Potassium content (%)	Calicum content (%)	Magnesium content (%)
l_0	2.03	0.52	1.72	0.82	0.29
l_1	2.09	0.63	1.68	1.05	0.25
l_2	2.12	0.67	1.46	1.20	0.22
F(2,22)	86.39**	436.55**	92.92**	1385.65**	77.85**
SEm ±	0.013	0.006	0.026	0.007	0.009
CD(0.05)	0.029	0.012	0.005	0.015	0.020
i_0	3.01	0.91	2.39	1.50	0.39
i_1	3.09	0.92	2.46	1.57	0.37
F(1,22)	66.11**	NS	NS	54.99**	NS
SEm ±	0.0067	0.0043	0.022	0.005	0.008
CD(0.05)	0.0140	-	-	0.0123	-
P_0	2.03	0.57	1.54	1.00	0.25
P_1	2.05	0.65	1.69	1.04	0.26
F(1,22)	6.46**	378.46**	56.94**	24.90**	NS
SEm ±	0.0067	0.004	0.022	0.005	0.008
CD(0.05)	0.0140	0.009	0.045	0.0123	-
l_0i_0	2.03	0.53	1.77	0.78	0.20
l_0i_1	2.04	0.52	1.75	0.86	0.19
l_1i_0	2.09	0.62	1.69	1.05	0.27
l_1i_1	2.10	0.64	1.66	1.05	0.23
l_2i_0	2.11	0.66	1.35	1.18	0.31
l_2i_1	2.13	0.68	1.49	1.22	0.32
F(2,22)	16.92**	6.31**	NS	15.35**	NS
SEm ±	0.011	0.0072	0.038	0.010	0.013
CD(0.05)	0.024	0.015	-	0.021	-
l_0P_0	2.01	0.49	1.69	0.78	0.19
l_0P_1	2.05	0.56	1.83	0.86	0.20
l_1P_0	2.09	0.60	1.57	1.05	0.26
l_1P_1	2.10	0.66	1.79	1.05	0.24
l_2P_0	2.11	0.62	1.35	1.20	0.30
l_2P_1	2.13	0.72	1.48	1.20	0.33
F(2,22)	4.603*	8.22**	6.14**	16.67**	NS
SEm ±	0.011	0.0072	0.038	0.010	0.013
CD(0.05)	0.024	0.015	0.078	0.021	-
l_0P_0	2.02	0.56	1.57	0.99	0.25
l_0P_1	2.03	0.65	1.63	1.02	0.27
l_1P_0	2.06	0.57	1.51	1.03	0.25
l_1P_1	2.07	0.65	1.77	1.06	0.25
F(1,22)	5.00*	NS	23.29**	NS	NS
SEm ±	0.010	0.006	0.030	0.0082	0.011
CD(0.05)	0.022	-	0.063	-	-

* Significant at 5% level
** Significant at 1% level

NS - Not significant

Inoculation did not significantly influence the total phosphorus content of plant.

Phosphorus application significantly influenced the phosphorus content of plant with p_1 recording a higher value than p_0.

The interactions LI and LP were found to significantly influence this parameter, with l_2i_1 and l_2p_1 recording maximum values.

4.2.5 Total potassium content of plant

The data on the total potassium content of plant are given in Table 8.

The data revealed that the different levels of lime significantly influenced the potassium content of plant. Increasing levels of lime decreased potassium content of plant.

Inoculation did not significantly influence the potassium content of plant.

Phosphorus application significantly increased the potassium content of plant with p_1 recording a higher value that p_0.

Among the interactions, LP and IP were significant with l_0p_1 and i_1p_1 recording the maximum values.

4.2.6 Total calcium content of plant

The mean data on the total calcium content of plant are presented in Table 8.

Liming had significant influence on the calcium content of plant. Increasing levels of lime increased calcium content with l_2 recording maximum value followed by l_1.

Inoculation significantly influenced calcium content of plant with i_1 recording a higher value than i_0.

Phosphorus application also had significant influence on Ca content with p_1 recording higher values than p_0.

Among the interactions only LI and LP significantly influenced this parameter, with l_2i_1 and both l_2p_i and l_2p_0 recording maximum values.

4.2.7 Total magnesium content of plants

The mean data on the total magnesium content of plant are given in Table 8.

The data revealed that liming had significant effect on the total magnesium content of plants. Increasing levels of lime decreased the magnesium content of plant with l_2 recording the minimum value and l_0 recording maximum value. Neither inoculation nor phosphorus application influenced the magnesium content of plants.

None of the interactions had any significant influence on this parameter.

4.3 Nutrient accumulation by plants

4.3.1 Total uptake of nitrogen

The mean data on the total uptake of nitrogen are presented in Table 9 and in Figure 8.

Liming significantly influenced the uptake of nitrogen. Increasing levels of lime increased the uptake of nitrogen with l_2 recording the maximum value.

Inoculation also had significant influence on uptake of nitrogen with l_1 recording a higher value than i_0.

The nitrogen uptake was significantly influenced by phosphorus application and p_1 showed a significantly higher value than p_0.

The interactions LI, LP, IP significantly influenced the uptake of nitrogen by plant with l_2i_1, l_2p_i and i_1p_1 recording maximum values, respectively.

4.3.2 Total uptake of phosphorus

The data on the total uptake of phosphorus are given in Table 9 and in Figure 8.

Lime application significantly influenced the phosphorus uptake of plants. Increasing levels of lime

Table 9. Effect of <u>Rhizobium</u> inoculation, liming and phosphorus application on the nutrient uptake of <u>Sesbania rostrata</u>

	Nitrogen uptake (kg/ha)	Phosphorus uptake (kg/ha)	Potassium uptake (kg/ha)	Calcium uptake (kg/ha)	Magnesium uptake (kg/ha)
l_0	80.72	19.81	56.55	31.67	7.49
l_1	105.06	32.49	86.72	54.35	13.14
l_2	120.44	40.30	106.26	72.51	19.11
F(2,22)	2766.92**	1047.45**	499.76**	7921.32**	231.47**
SEm ±	0.538	0.452	1.583	0.323	0.539
CD(0.05)	1.117	0.937	3.285	0.671	1.119
i_0	149.87	45.29	122.56	77.37	19.44
i_1	156.35	47.30	126.97	81.36	20.30
F(1,22)	96.204**	13.23**	5.166*	101.19**	NS
SEm ±	0.439	0.313	1.293	0.264	0.440
CD(0.05)	0.912	0.765	2.682	0.548	-
P_0	100.70	26.30	78.04	51.93	12.95
P_1	103.44	35.43	89.32	53.89	13.54
F(1,22)	38.81**	193.96**	63.21**	55.29**	NS
SEm ±	0.439	0.323	1.293	0.264	0.440
CD(0.05)	0.912	0.765	2.682	0.548	-
l_0i_0	79.61	19.42	52.62	29.94	7.45
l_0i_1	81.83	20.20	60.48	33.80	7.54
l_1i_0	103.20	31.55	87.00	53.79	13.33
l_1i_1	106.93	33.44	86.44	54.91	12.96
l_2i_0	116.94	39.62	105.50	71.01	18.11
l_2i_1	123.95	40.97	107.02	74.00	20.10
F(2,22)	10.36**	NS	NS	9.282**	NS
SEm ±	0.761	0.638	2.240	0.457	0.763
CD(0.05)	1.580	-	-	0.948	-
l_0P_0	79.09	17.64	52.70	30.13	7.02
l_0P_1	82.35	21.98	60.40	33.61	7.97
l_1P_0	102.57	30.37	79.64	53.56	12.93
l_1P_1	107.57	34.62	93.81	55.14	13.36
l_2P_0	118.42	36.89	101.77	72.10	18.91
l_2P_1	120.46	43.70	110.55	72.92	19.30
F(2,22)	11.35**	5.186*	3.645*	6.996**	NS
SEm ±	0.761	0.602	2.240	0.457	0.763
CD(0.05)	1.580	1.325	4.647	0.948	-
i_0P_0	97.80	27.27	77.53	50.45	12.57
i_0P_1	102.98	33.12	85.89	52.71	13.36
i_1P_0	103.18	29.33	78.54	53.40	13.34
i_1P_1	104.85	33.75	90.75	55.07	13.73
F(1,22)	13.67**	NS	NS	NS	NS
SEm ±	0.622	0.522	1.829	0.374	0.623
CD(0.05)	1.230	-	-	-	-

* significant at 5% level NS - Not significant
** significant at 1% level

increased phosphorus uptake with l_2 recording the highest value, followed by l_1.

Inoculation had significant effect on phosphorus uptake with i_1 recording a higher value than i_0.

Phosphorus application significantly influenced the phosphorus uptake of plant with p_1 being superior to p_0.

Among the interactions, only LP had significant influence on this parameter with l_2p_1 recording the highest value.

4.3.3 Total uptake of potassium

The data on the total uptake of potassium are given in Table 9 and in Figure 8.

The data revealed that liming significantly influenced the potassium uptake of plant. Increasing lime levels increased the potassium uptake with l_2 recording the highest value, followed by l_1.

Inoculation had significant effect on potassium uptake with i_1 being superior to i_0.

Phosphorus application had significant influence on potassium uptake with p_1 recording a higher value than p_0.

Among the interactions, only LP had significant influence on this parameter, with l_2p_i recording the maximing value.

4.3.4 Total uptake of calcium

The data on the total uptake of calcium are presented in Table 9 and in Figure 8.

The plant uptake of calcium was significantly influenced by liming. Increasing levels of lime increased the uptake of calcium with l_2 recording the maximum value, followed by l_1.

Inoculation also had significant influence on the uptake of calcium with i_1 being superior to i_0.

Phosphorus application significantly influenced the uptake of calcium with p_1 recording a higher value than p_0.

Among the interactions only LI and LP significantly influenced this parameter, with l_2i_1 and l_2p_1 recording maximum values, respectively.

4.3.5 Total uptake of magnesium

The data on the total uptake of magnesium are given in Table 9 and in Figure 8.

The data revealed the significant influence of liming in the uptake of magnesium. Increasing levels of lime increased the uptake with l_2 recording the highest value, followed by l_1.

Neither inoculation nor phosphorus application significantly influenced magnesium uptake by plants.

None of the interactions exerted any significant influence on this parameter.

4.4 Soil analysis

4.4.1 Available nitrogen content of the soil after the experiment

The data on the available nitrogen content of the soil after the experiment are given in Table 10.

It is seen that liming significantly influenced the nitrogen content of the soil. Increasing levels of lime application increased the available nitrogen content with l_2 recording the maximum value.

Inoculation had significant influence on the available nitrogen content of the soil with i_1 being superior to non-inoculation i_0. Phosphorus application significantly influenced nitrogen of the soil.

All the interactions LP, LI and IP significantly influenced this parameter with l_2i_1, l_2p_1 and i_1p_1 recording the highest values, respectively.

4.4.2 Available phosphorus content of the soil after the experiment

The data on the available phosphorus content of the soil after the experiment are presented in Table 10.

Table 10. Effect of *Rhizobium* inoculation, liming and phosphorus application on the available nutrient status of the soil after the experiment.

	Soil available Nitrogen. (kg/ha)	Soil available Phosphorus (kg/ha)	Soil available potassium (kg/ha)	Soil available calcium (kg/ha)	Soil available magnesium (kg/ha)
l_0	318.70	28.81	111.28	177.00	133.92
l_1	424.75	38.44	110.85	216.33	130.33
l_2	503.50	42.40	110.73	251.75	131.42
F(2,22)	10836.03**	444.66**	NS	197.98**	NS
SEm ±	1.267	0.468	0.644	3.758	4.45
CD(0.05)	2.628	0.971	-	7.795	-
i_0	594.95	54.82	166.25	322.67	198.16
i_1	652.00	54.82	166.61	322.42	197.50
F(1,22)	1366.73**	NS	NS	NS	NS
SEm ±	1.028	0.382	0.526	3.068	3.636
CD(0.05)	2.134	-	-	-	-
P_0	408.47	31.96	110.78	215.28	132.00
P_1	422.83	41.14	111.13	214.78	131.78
F(1,22)	194.90**	575.31**	NS	NS	NS
SEm ±	1.028	0.382	0.526	3.068	3.636
CD(0.05)	2.134	0.793	-	-	-
l_0i_0	292.08	28.55	111.04	176.00	132.00
l_0i_1	345.33	29.07	111.52	178.00	135.33
l_1i_0	419.67	38.69	110.92	217.83	131.50
l_1i_1	429.83	38.19	110.76	214.83	129.16
l_2i_0	478.16	42.40	110.53	251.50	132.33
l_2i_1	528.33	42.35	110.94	252.00	132.50
F(2,22)	183.92**	NS	NS	NS	NS
SEm ±	1.781	0.662	0.912	5.313	6.30
CD(0.05)	3.695	-	-	-	-
l_0P_0	306.25	23.47	111.48	178.00	132.83
l_0P_1	331.16	34.16	111.08	176.00	135.00
l_1P_0	424.00	34.00	110.90	215.83	131.50
l_1P_1	425.00	42.87	110.76	216.83	129.16
l_2P_0	495.16	38.42	109.95	252.00	131.67
l_2P_1	511.83	46.37	111.57	252.50	131.16
F(2,22)	44.46**	4.42*	NS	NS	NS
SEm ±	1.781	0.662	0.912	5.313	6.30
CD(0.05)	3.695	1.373	-	-	-
i_0P_0	383.72	32.06	110.72	214.76	132.11
i_0P_1	409.55	41.03	110.94	215.44	132.11
i_1P_0	432.22	31.86	110.84	215.78	131.89
i_1P_1	436.11	41.24	111.31	214.11	131.44
F(1,22)	124.38**	NS	NS	NS	NS
SEm ±	1.454	0.540	0.744	4.34	5.15
CD(0.05)	3.017	-	-	-	-

* Significant at 5% level
** Significant at 1% level

NS - Not significant

Liming significantly influenced the available phosphorus content of the soil. Increasing lime levels increased the available phosphorus content with l_2 recording the highest value, followed by l_1.

Inoculation did not influence the available phosphorus content of the soil.

Phosphorus application significantly influenced the available phosphorus content of the soil.

Among the interactions only LP had significant influence on this parameter with l_2p_1, recording the highest value.

4.4.3 Available potassium content of the soil after the experiment

The data on the available potassium content of the soil after the experiment are presented in Table 10.

Treatments such as liming, inoculation and phosphorus application and their interaction did not significantly influence the available potassium content of the soil.

4.4.4 Available calcium content of the soil after the experiment

The data on the available calcium content of the soil are presented in Table 10.

The data revealed that liming had significant influence on the available calcium content of the soil. Increasing liming levels, increased the soil available calcium with l_2 recording the highest value, followed by l_1.

Inoculation and phosphorus application did not significantly influence the available calcium content of the soil.

None of the interactions had any significant influence on this parameter.

4.4.5 Available magnesium content of the soil after the experiment

The data on the available magnesium content of the soil are presented in Table 10.

The results on this parameter follow the same pattern as that of available potassium content of the soil. Neither the treatments nor their interactions exerted any significant influence on the available magnesium content of the soil.

4.4.6 Soil organic carbon after the experiment

The data on the soil organic carbon after the experiment are given in Table 11.

Neither the main treatments nor their interactions exerted any significant influence on this parameter.

4.4.7 Soil pH after the experiment

The data on the soil pH after the experiment are given in Table 11.

Liming significantly influenced the pH of soil. Increasing levels of lime increased soil pH, with l_2 recording the highest soil pH value, followed by l_1.

Inoculation and phosphorus application did not significantly influence the soil pH. None of the interactions exerted any significant effect on this parameter.

4.4.8 Rhizobium population in the rhizosphere after the experiment

The data on the Rhizobium population in the rhizosphere are presented in Table 11.

It is observed from the data presented in Table 11 that liming significantly influenced the rhizobium population in the rhizosphere. Increasing liming levels increased the Rhizobium population with l_2 recording the highest value, followed by l_1.

Inoculation significantly influenced the Rhizobium population with i_1 being superior to no inoculation.

Table 11. Effect of <u>Rhizobium</u> inoculation, liming and phosphorus application on soil organic carbon, soil pH and <u>Rhizobium</u> population after the experiment.

	Soil organic carbon (%)	Soil pH	<u>Rhizobium</u> population in the Rhizophere (10^4/g soil)
l_0	0.81	5.21	20.83
l_1	0.80	5.55	33.83
l_2	0.80	5.93	69.08
F(2,22)	NS	572.97**	998.25**
SEm ±	0.008	0.0209	1.117
CD(0.05)	-	0.0434	2.317
i_0	1.19	8.34	59.75
i_1	1.20	8.35	64.00
F(1,22)	NS	NS	9.64**
SEm ±	0.0065	0.016	0.912
CD(0.05)	-	-	1.892
p_0	0.80	5.57	37.78
p_1	0.80	5.56	44.72
F(1,22)	NS	NS	57.93**
SEm ±	0.0065	0.016	0.912
CD(0.05)	-	-	1.892
l_0i_0	0.81	5.22	21.50
l_0i_1	0.81	5.22	20.17
l_1i_0	0.79	5.55	28.83
l_1i_1	0.81	5.55	38.83
l_2i_0	0.79	5.92	64.17
l_2i_1	0.80	5.93	69.30
F(2,22)	NS	NS	15.56**
SEm ±	0.011	0.029	1.58
CD(0.05)	-	-	3.278
l_0p_0	0.81	5.22	18.33
l_0p_1	0.81	5.22	23.33
l_1p_0	0.80	5.55	33.00
l_1p_1	0.80	5.55	34.67
l_2p_0	0.79	5.93	62.00
l_2p_1	0.80	5.92	76.16
F(2,22)	NS	NS	16.77**
SEm ±	0.011	0.029	1.58
CD(0.05)	-	-	3.278
i_0p_0	0.79	5.57	39.22
i_0p_1	0.80	5.56	40.44
i_1p_0	0.80	5.57	36.33
i_1p_1	0.81	5.57	49.00
F(1,22)	NS	NS	39.33**
SEm ±	0.0093	0.024	1.290
CD(0.05)	-	-	2.676

** Significant at 1% level NS - Not significant
* Significant at 5% level

Table 12. Economics of cultivation of *Sesbania rostrata* as a green manure

Treat- ments	Cost of production excluding the treatments (Rs./ha)	Addl. cost due to the treatments (Rs./ha)	Total cost of Production (Y) (Rs./ha)	Green matter yield (t/ha)	Value (X) Rs.	Net profit (Rs.) (X - Y)	Cost-benefit ratio (X/Y)
l_0	3348.00	Nil	3348.00	12.09	3324.75	-23.25	0.99
l_1	3348.00	375.00	3723.00	16.27	4474.25	751.25	1.20
l_2	3348.00	750.00	4098.00	18.72	5148.00	1050.00	1.26
i_0	3348.00	Nil	3348.00	23.35	6421.25	3073.25	1.91
i_1	3380.00	25.00	3373.00	23.75	6525.75	3152.75	1.93
p_0	3348.00	Nil	3348.00	15.53	4270.75	922.75	1.28
p_1	3348.00	187.50	3535.50	15.85	4358.75	823.25	1.23

PRICE (Rs.)

One ton green manure 275/-

Lime (per kg) 1.5

P_2O_5 (per kg) - 6.25

Rhizobium culture (per packet) - 5/-

Phosphorus application had significant influence on the Rhizobium population with p_1 recording a higher value than p_0.

The interactions LP, LI and LP influenced the Rhizobium population in the rhizosphere significantly with l_2p_1, l_2i_1 and i_1p_1 recording the highest values respectively.

4.4.9 Economics of cultivation

The data on the net returns are presented in Table 12. All treatments registered significantly higher net profits than the control. As the level of liming was increased from l_0 to l_2, the net profit also increased, with the maximum net profit being obtained at l_2. Of the levels of inoculation, i_1 recorded higher value than i_0. In the case of phosphorus it can be seen that application of phosphorus recorded a lower net profit compared with no application. Among liming levels, l_2 recorded the highest cost benefit ratio. Between inoculation and no inoculation, the former recorded highest cost-benefit ratio. No application of phosphorus gave a better cost-benefit ratio when compared with phosphorus application.

DISCUSSION

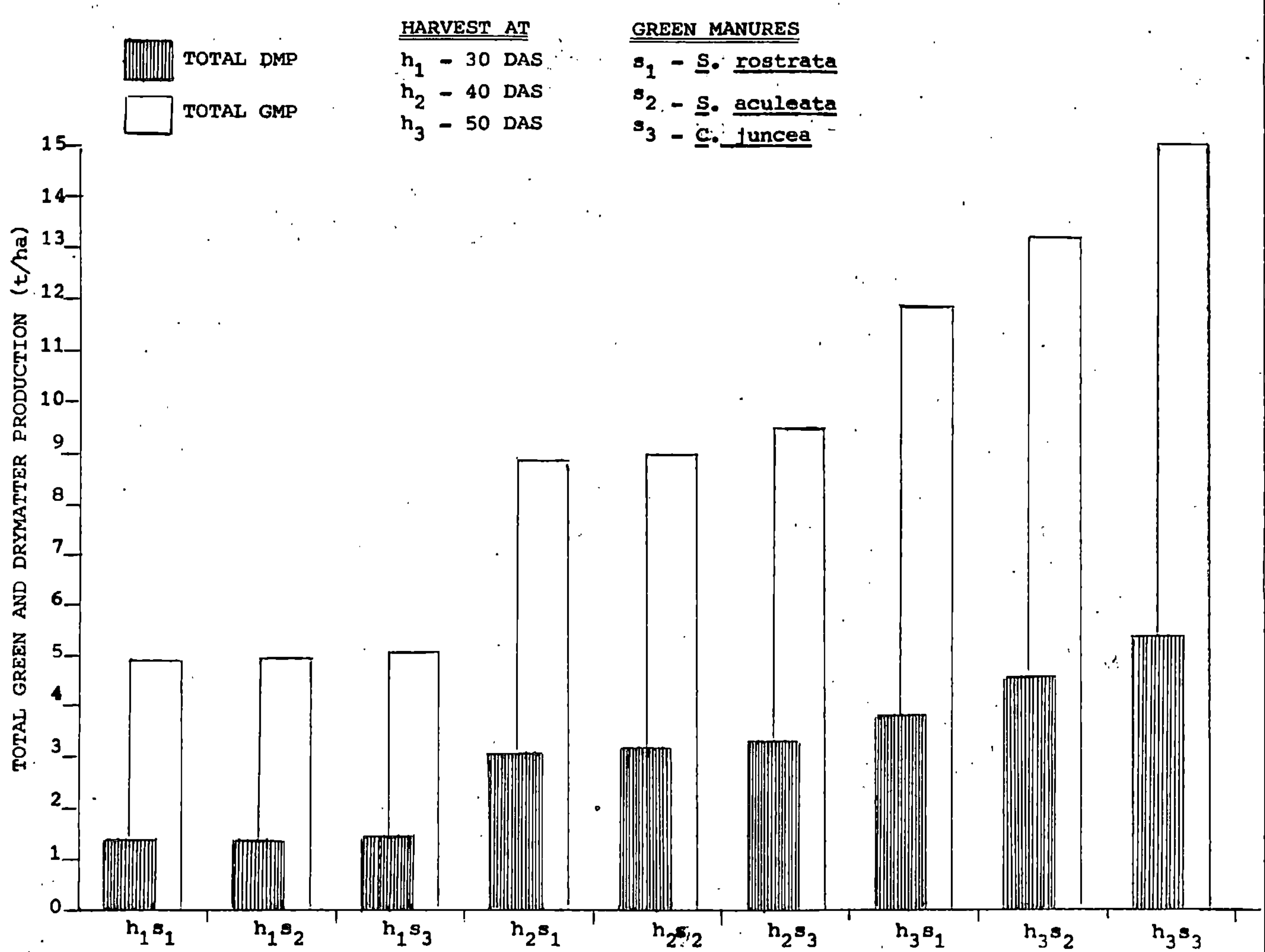

Fig 3. Effect of days of harvest and type of green manure on the total green and drymatter production (t/ha).

The total green matter and dry matter productions also followed the same pattern as that of plant height. The green matter production and dry matter production increased from 5.14 to 13.40 and 1.44 to 4.61 t/ha respectively, with increase in days taken for harvest from 30 DAS to 50 DAS. Crotalaria juncea recorded the maximum green matter production of 9.98 t/ha and dry matter production of 3.40 t/ha compared to the other two legumes. Interaction effects were also found to be significant in the case of these two parameters.

Crotolaria juncea at 30 and 50 DAS produced 5.14 and 14.98 t/ha respectively, of green matter. Thus, a nearly three fold increase (ie 300% increase) in green matter production was achieved when the days of harvest was delayed from 30 to 50 DAS, whereas Sesbania rostrata could register only a two fold increase in green matter production for the same period of growth (ie from 4.96 t/ha to 11.94 t/ha).

Crotolaria juncea produced 1.39, 3.33 and 5.36 t/ha of dry matter at 30, 40 and 50 DAS. Between, 30 and 40 DAS, the dry matter production per day was 0.19 t, whereas it was 0.21 tons per day between 40 and 50 DAS. For Sesbania rostrata , the increase in dry matter per

PLATE I. <u>Crotolaria juncea</u> at harvest (50 DAS)

PLATE I

DISCUSSION

EXPERIMENT I

An investigation was undertaken to determine the biomass production and nutrient accumulation of Sesbania rostrata in comparison with other green manures viz. Sesbania aculeata and Crotalaria juncea. The results obtained are discussed below.

5.1 Growth characters

The data revealed that time of harvest significantly increased the plant height. There was an increase in plant height from 50.67 cm to 122.36 cm as the days of harvest was delayed from 30 to 50 DAS. Significant difference in height was noticed with type of legume also. Crotalaria juncea recorded the maximum height (108.71 cm) whereas Sesbania rostrata showed the minimum height (74.21 cm). Interaction effects between time of harvest and type of legume was also significant. Increase in plant height for Crotolaria juncea was 47.9 cm (4.79 cm per day) when the day of harvest was delayed from 30 to 40 DAS; whereas between 40 and 50 DAS, the increase in plant height was 47.07 cm (4.70 cm per day). For Sesbania rostrata the corresponding increases in plant height per day was 2.52 cm and 3.04 cm respectively.

PLATE II. Sesbania rostrata at harvest (50 DAS)

PLATE II

day was 0.17 t between 30 and 40 DAS; for the period between 40 and 50 DAS, it was only 0.07 t per day. Thus even though, flowering stage recorded the highest dry matter production in Sesbania rostrata the rate of increase of dry matter per day was less when compared with the dry matter production per day, between 30 and 40 DAS.

Growth of an annual plant follows a general pattern and growth is expressed as increase in dry weight or height of the plant and there is a fairly constant relationship between the measure of growth employed and time. The general pattern is one of an initial small increase in size, followed by large increases. During the final stages the size of plant increases very slowly or almost ceases (Tisdale et al. 1985). Since, the harvests of the green manures were carried out at flowering stage (50 DAS), the plants must have been at their peak growth stage, and hence the above parameters viz plant height, total GMP and total DMP recorded the maximum values. Similar results were obtained by Dreyfus et al. (1985); Sharma and Murty (1988), and numerous other workers in the three green manures. The superiority of Crotolaria juncea over the other two green manures can be attributed to the species character wherein it has the inherent capacity

PLATE III. *Sesbania aculeata* at harvest (50DAS)

PLATE IV. Root nodules of *Sesbania aculeata* at harvest (50 DAS)

PLATE III

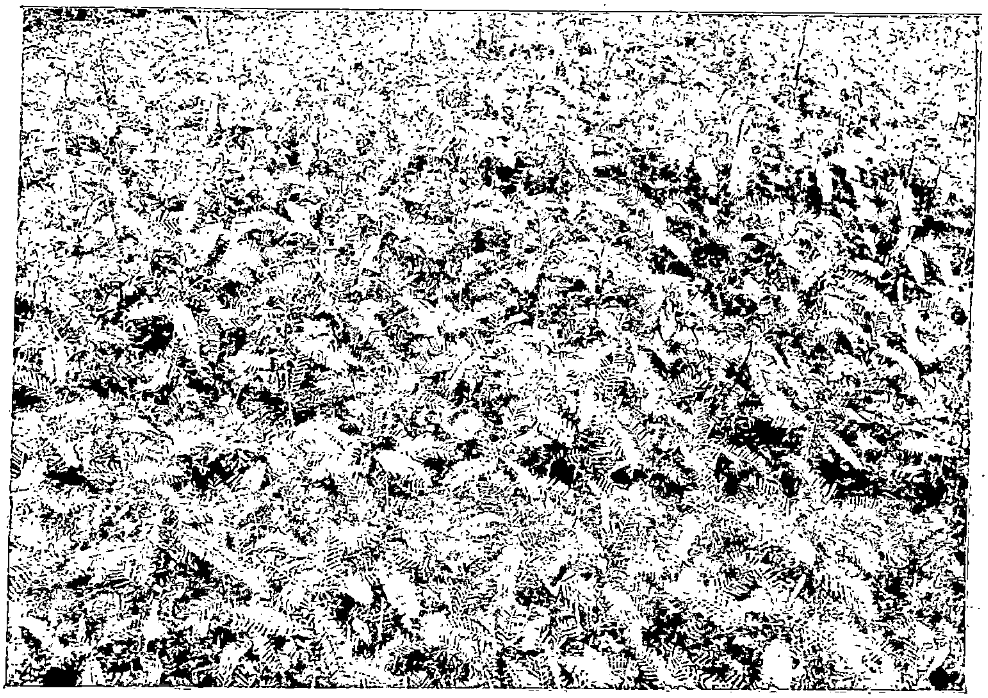

PLATE IV

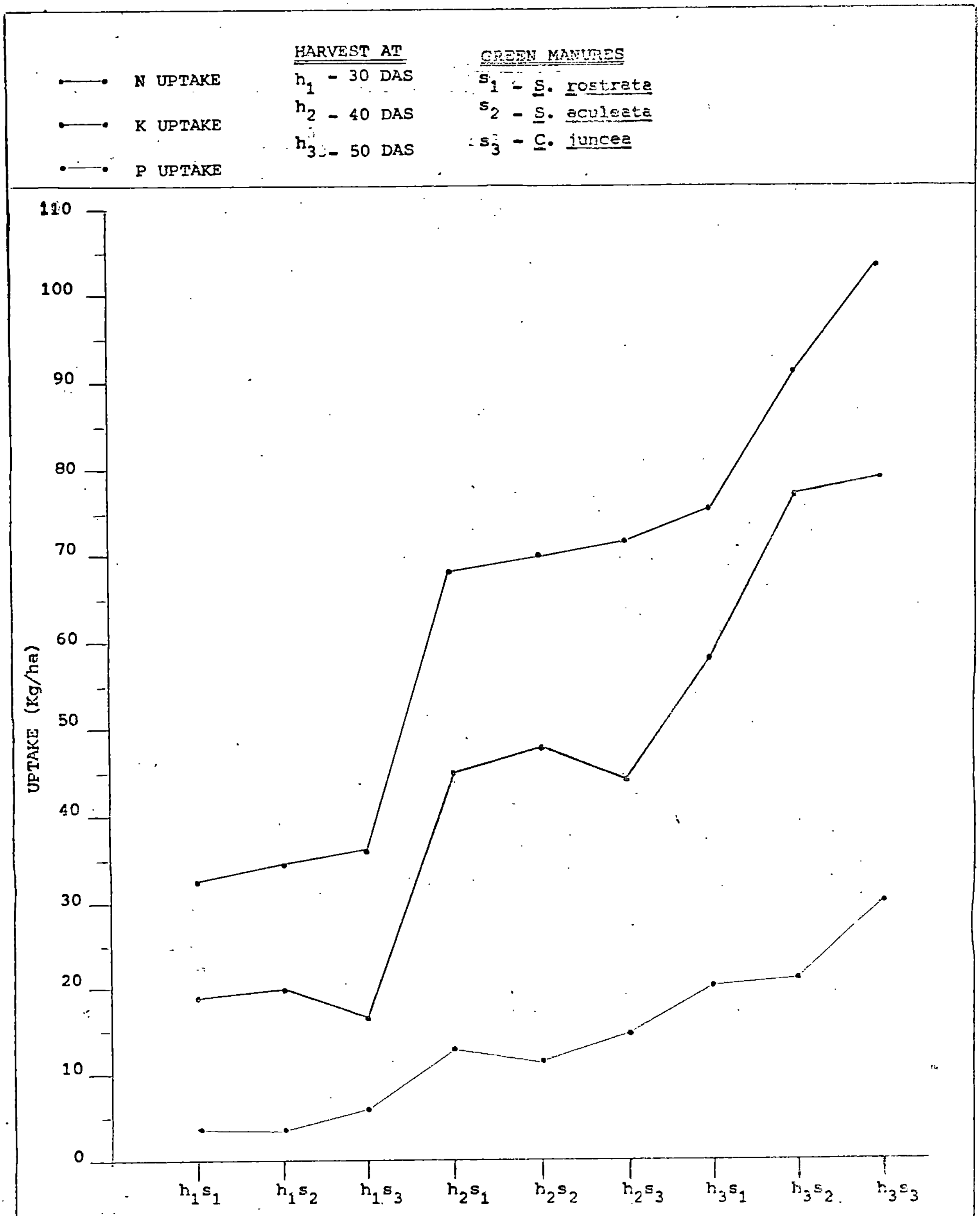

Fig 4. Effect of days of harvest and type of green manure on N,P & K uptake.

to produce greater height and more biomass than the other two green manures under the agro-climatic condition of Southern Kerala. The poor performance of Sesbania rostrata in terms of biomass production can be attributed to the low soil moisture conditions that prevailed at the experimental site. Many workers (Dreyfus *et al.* 1985; Gines *et al.* 1987; Anon. 1985) have reported the superior performance of Sesbania rostrata in terms of production under flooded conditions, than under non-flooded conditions.

5.2 Nodulation characteristics

An appraisal of Table 2 revealed that time of harvest significantly influenced the nodule characteristics. As the time of harvest was delayed upto 50 DAS, the number of root nodules per plant increased from 20.97 to 40.92 per plant and the dry weight from 0.054 to 0.246 g per plant. Nodule number was doubled with delay in days of harvest from 30 to 50 DAS; for the corresponding period, the increase in nodule weight was nearly five times. This increase in nodule weight with delays in days of harvest can be attributed to the better development and increased size of the nodules. Sesbania aculeata recorded the maximum number of root nodules (40.70/plant) and dry weight of root nodules(0.209 g/plant)

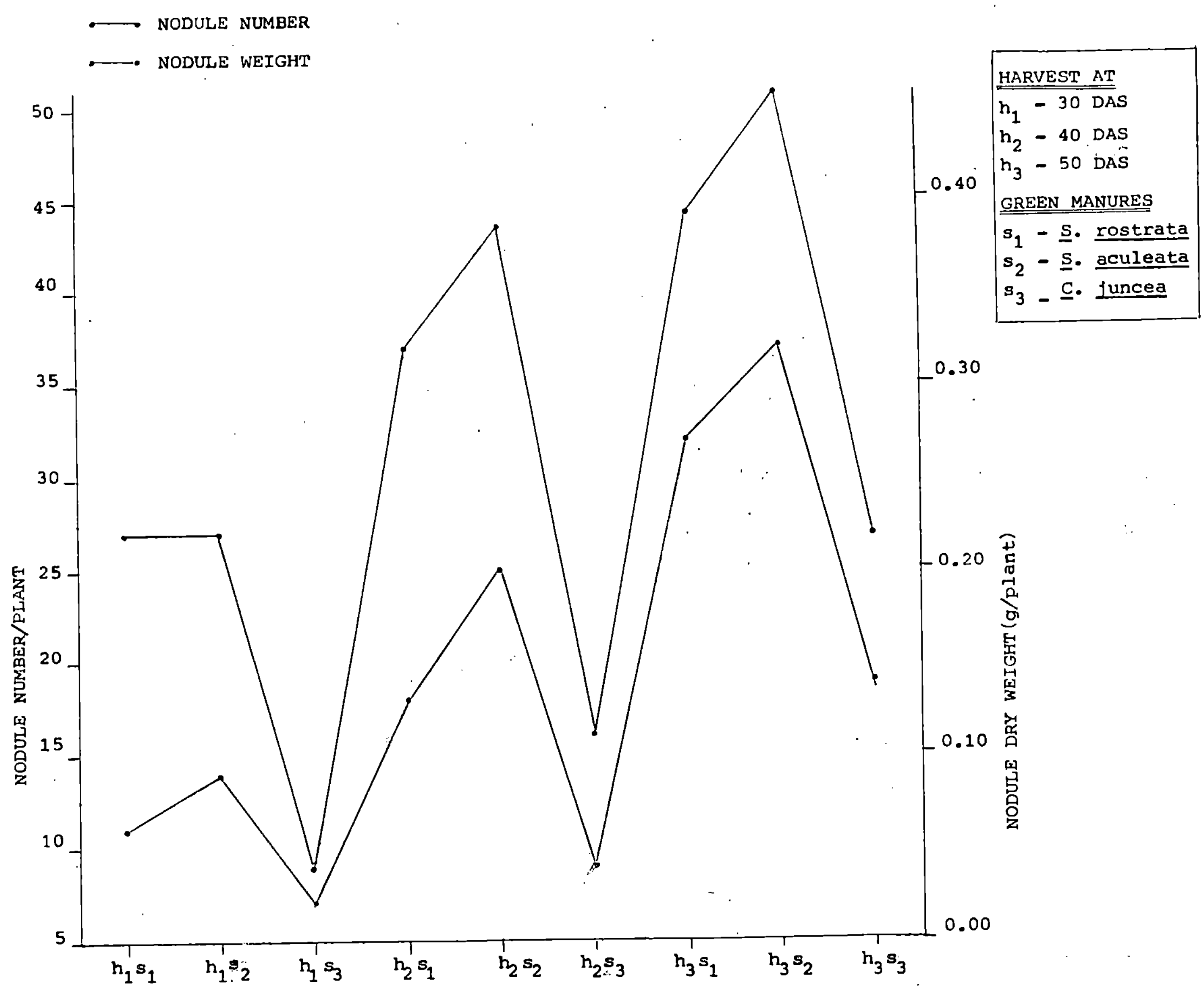

Fig 5. Effect of days of harvest and type of green manure on nodule number and dry weight.

and the minimum by Crotolaria juncea (17.26 and 0.073 g/plant) respectively. Interaction effects between time of harvest and type of legume were also found to be significant. Sesbania aculeata at 50 DAS recorded the maximum nodule number (1.55 per plant) and nodule weight (0.329 g per plant), followed by Sesbania rostrata (44.33 and 0.27 g per plant) respectively at the time of harvest (50 DAS).

It is generally seen that the number of nodules produced by legumes increases with increase in age and maximum nodule activity occurs at the flowering stage in legumes (Dobereiner, 1977). The results of this experiment are in agreement with the above finding. Even though growth performance of Crotolaria juncea was invariably better than the other two green manures under the agro-climatic condition of Trivandrum district, the better nodulation exhibited by Sesbania aculeata can be attributed to the inherent capacity of the plant to produce more nodules than the other green manures, given the same environmental conditions.

5.3 Chemical analysis

Time of harvest significantly influenced the nitrogen content of root nodules and nitrogen, phosphorus, potassium, calcium and magnesium contents of the plant. As the time of harvest was delayed upto 50 DAS, the nitrogen content of the root nodules increased from 0.49 to 1.20 per cent. Maximum nodule activity occurs at flowering stage (Dobereiner, 1977). So naturally the maximum nitrogen content in the root nodule was also noted during the period. The results of the present investigation also are in agreement with this finding. But, the nitrogen content of plants decreased from 2.39 per cent at 30 DAS to 1.97 per cent at 50 DAS. The phosphorus content of plant increased from 0.31 to 0.52 per cent, potassium content from 1.36 to 1.55 per cent, calcium content from 0.69 to 0.88 per cent and magnesium content from 0.22 to 0.31 per cent respectively, when the time of harvest was delayed from 30 to 50 DAS.

The type of legumes also influenced the nitrogen content of root nodules and phosphorus, potassium, calcium and magnesium contents of plants. Nodules of Sesbania aculeata contained 0.94 per cent nitrogen, whereas root nodules of Sesbania rostrata recorded a minimum value of 0.59 per cent. With regard to phosphorus content, Crotolaria juncea recorded a maximum value of 0.46 per cent and Sesbania aculeata, the least value of 0.36 per cent. This can be attributed to the species character, wherein each plant has its own inherent ability to absorb and accumulate more of a nutrient, in its parts. In the case of potassium, Sesbania aculeata recorded the maximum content of 1.54 per cent. For calcium, Sesbania rostrata recorded the maximum Ca content of 0.87 per cent, whereas for magnesium, Crotalaria juncea recorded a maximum value of 0.39 per cent. This can be attributed to the inherent ability of a plant to absorb and accumulate more of a particular nutrient. Increase in calcium content of plants decreased the magnesium content and vice versa. Sesbania rostrata which recorded the maximum calcium content (0.87 per cent) had the lowest magnesium content (0.20 per cent) whereas Crotolaria juncea which had the highest magnesium content (0.39 per cent) had the lowest calcium content (0.66 per cent). This inverse relationship can be attributed to the competition between Ca^{2+} and Mg^{2+} ions inside the plant ie. accumulation of calcium ions is inhibited by magnesium ions and vice versa (Black (1967); Russel (1973); Fried and Broeshart, (1967). Interaction effect was found to be significant only in the case of root nodule nitrogen. For other parameters, none of the interactions proved to be significant.

A decrease in the nitrogen content of the plant was noticed as the age advanced. Similar results of decrease in nitrogen content with increase in age were obtained by Alonso (1934), Hernandez *et al.* (1957), Rajbhandari (1984), Bharadwaj and Dev (1985) in many leguminous green manures.

The plants were harvested at flowering stage. Nitrogen in the plant might have been utilised for the formation of reproductive organs and this may have resulted in a decrease in nitrogen content. Increases in contents of phosphorus, potassium, calcium and magnesium were observed with delays in harvest from 30 to 50 DAS. This can be attributed to increased uptake of nutrients as the plants remained in the field for a longer period.

5.4 Nutrient uptake

5.4.1 Uptake of nitrogen by the plants

An appraisal of Table 4 reveals that by delaying harvest of the green manures from 30 to 50 DAS the nitrogen uptake was increased from 34.35 kg/ha to 90.13 kg/ha. Among the green manures *Crotolaria juncea* had the maximum nitrogen accumulation of 70.54 kg/ha whereas *Sesbania rostrata* showed the least value of 55.87 kg/ha.

In this connection, it is worth mentioning the fact that *Crotolaria juncea* harvested at 50 DAS, gave the highest nitrogen yield of 103.78 kg/ha, whereas *Sesbania* *rostrata* at 50 DAS yielded only 75.60 kg/ha.

Nitrogen content of the plant had a negative relationship with increase in days to harvest, the reason for which has been discussed earlier in detail. According to Tanaka *et al.* (1964), the uptake of plant nutrient at any stage of growth is mainly related to dry matter production, and the nutrient uptake is controlled by factors like nutrient availability in soil, nutrient absorption power of roots and rate of increase in dry matter. Appreciable increases in dry matter production of the three green manures have been observed with delay in harvest from 30 to 50 DAS. This increase in dry matter production would have resulted in an increased uptake of the nutrients, which is in confirmity with the view expressed by Tanaka *et al.* (1964).

The influence of the interaction effect may be attributed to the additive effects of the individual treatments. Increases in nitrogen uptake with delay in harvest was also reported by several workers like Rajbhandari (1984), Meelu *et al.* (1985a), Furoc *et al.* (1985) and Gines *et al.* (1987).

Each species of plant differs in its capacity to absorb nutrients. This ability is mainly determined by its genetic make up. The maximum uptake of nitrogen exhibited by *Crotolaria juncea*, can be attributed to its varietal character.

5.4.2 Uptake of phosphorus by plants

A perusal of the data in Table 4 reveals that delaying harvest from 30 to 50 DAS, increased the uptake of phosphorus by green manures from 4.40 kg/ha to 23.88 kg/ha. The influence of increasing dry matter production in increasing the nutrient uptake has already been discussed in detail. Among the green manures, Crotolaria juncea showed the maximum phosphorus uptake value of 16.79 kg/ha, whereas Sesbania aculeata showed the least uptake of 12.02 kg/ha. Crotolaria juncea at 50 DAS recorded the maximum uptake of 30.07 kg/ha. The highest phosphorus content noted in Crotolaria juncea can be attributed to the species character of the green manure. Moreover the growth performance of this green manure in the agro-climatic condition of the experimental site was much better than the other two green manures as is revealed by the data on green and dry matter accumulation. Increase in phosphorus content of the green manures with delay in harvest upto 50 DAS was observed in the green manures and the reasons for it has been discussed in detail earlier. All these factors may have influenced in the maximum uptake of phosphorus by Crotolaria juncea.

5.4.3 Uptake of potassium, calcium and magnesium by plants

The data presented in Table 4 indicate the positive influence in the uptake of K, Ca and Mg by delaying the harvest upto 50 DAS. Delaying the harvest of the green manures upto 50 DAS, increased the potassium uptake from 19.42 kg/ha to 71.37 kg/ha, calcium uptake from 9.85 to 40.13 kg/ha and magnesium uptake from 3.26 to 14.93 kg/ha.

Increases in the plant nutrient content with delay in harvest have been observed in this experiment and discussed in detail. Increases in dry matter yield with delay in harvest have led to increases in nutrient content which in turn resulted in a higher uptake of the K, Ca and Mg. The reason for the same has been discussed earlier.

Type of green manure also significantly influenced the uptake of potassium, calcium and magnesium. In the case of potassium and calcium the maximum uptake was recorded by <u>Sesbania aculeata</u> with values of 48.45 kg/ha and 27.17 kg/ha respectively. <u>Sesbania rostrata</u> proved to be significantly inferior to <u>Sesbania aculeata</u> by registering an uptake value of 40.69 kg/ha and 24.91 kg/ha respectively for these two elements. In the case of magnesium, the highest uptake was recorded by <u>Crotolaria</u>

juncea at 13.85 kg/ha, whereas *Sesbania rostrata* recorded the lowest value of 6.42 kg/ha. These differences on uptake can be attributed to the genetic makeup of the plants.

5.4.4 Soil nutrient status after the experiment

Available nitrogen content of the soil was significantly influenced only by days of harvest (Table 5). Progressive increase in available nitrogen status of soil from 193.78 kg/ha to 273.44 kg/ha was obtained when the harvest was delayed from 30 to 50 DAS.

Increase in available nitrogen status of soil with delay in harvest date can be linked with nodule activity. The data on nodule characteristics discussed earlier have shown that the root nodule number and weight were significantly increased with delay in harvest. The maximum value for root nodule number and weight for the three green manures was obtained at 50 DAS. Since the maximum nodule activity was seen at 50 DAS, the quantity of N fixed at this time also be the highest which might have enriched the available nitrogen status of soil.

Similar increases in available nitrogen status of soil after a crop of legumes has also been reported by many workers like Ramanagowda (1981), Rose (1963) and Dobereiner (1977). The status of other nutrients viz.

phosphorus, potassium, calcium or magnesium in soil after the experiment was not significantly influenced by days of harvest, type of green manure or their interactions.

5.4.5 Soil organic carbon

A perusal of Table 5 shows that time of harvest, type of green manure and their interaction did not significantly influence the soil organic carbon after the experiment.

5.4.6 Soil pH

Reference to Table 5 shows that only the type of green manure significantly influenced the soil pH. Soil in which Sesbania aculeata was grown, registered a pH of 5.2, compared with a pH 5.3 for soils in which Sesbania rostrata and Crotolaria juncea were grown. A perusal of data on nodule characteristics reveals that Sesbania aculeata has the maximum number of root nodules in the experiment. This is a clear indication of the intense activity of Rhizobia in the rhizosphere of this green manure plant. This small decrease in pH observed may probably be due to the accumulation of carbondioxide produced by minerlization activity and respiration of aerobic bacteria. According to Nicol and Turner (1957), carbondioxide depressed the pH of even acid soils. Similar decreases in soil pH, as a result of growing *Sesbania aculeata* was also reported by Sharma *et al.* (1988).

From the discussion, it can be concluded that the optimum time of harvest of the green manures during third crop season in rice fallows is at 50 DAS (flowering stage), since all the parameters investigated in this experiment, showed a maximum value at this period. Among the green manures, *Crotolaria juncea* proved to be superior, in terms of green matter yield, dry matter yield and nutrient uptake followed by *Sesbania aculeata*. The performance of *Sesbania rostrata* was not at all satisfactory under the agroclimatic conditions existing in Southern Kerala during the summer season of 1989. The present study reveals the superiority of *Crotolaria juncea* as a green manure under Trivandrum conditions during the summer season as compared with the other green manures tried.

EXPERIMENT II

A study was conducted at the College of Agriculture, Vellayani to determine the effect of liming, *Rhizobium* inoculation and phosphorus application on the biomass productivity and nutrient accumulation of *Sesbania rostrata*. The results of the study are discussed below.

5.1 Growth characters

5.1.1 Plant height, green matter and dry matter yield

The results on the plant height are presented in Table 6. An appraisal of the data in the table indicates that liming significantly influenced this parameter. Plant height increased from 106.34 cm to 168.23 cm when liming level was increased to 500 kg/ha.

Inoculation did not significantly influence the plant height. Phosphorus application had a significant positive influence on plant height. Phosphorus application at 30 kg/ha increased plant height to 135.56 cm compared to 132.75 cm at no application. The interactions did not significantly influence this parameter.

A perusal of Table 6 indicates that there was a progressive increase in green matter production from 12.09 t/ha at zero lime per hectare to 18.72 t/ha at 500 kg lime per hectare. Inoculation significantly influen-

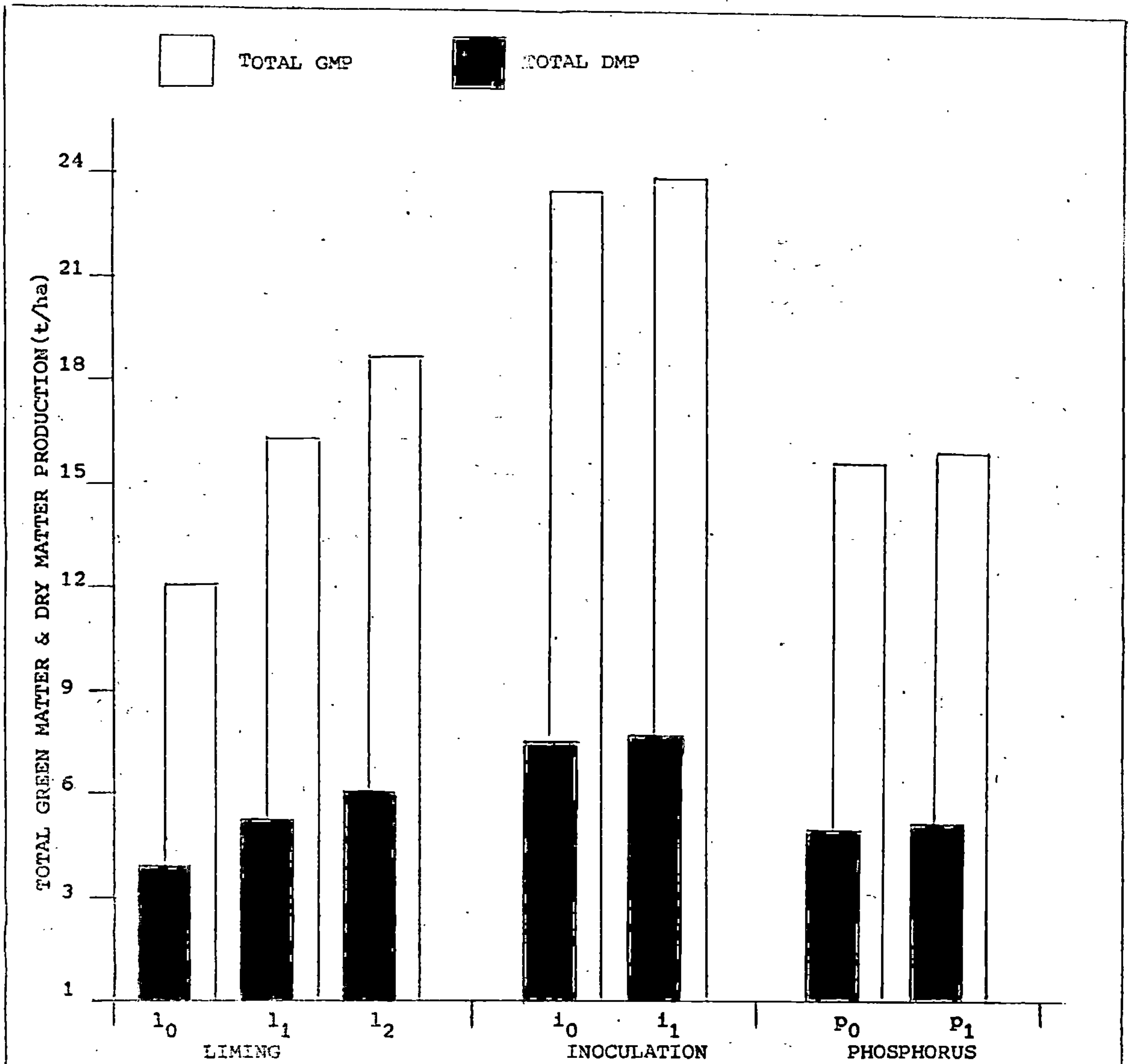

Fig **6** . Effect of liming , rhizobium inoculation and phosphorus application on total green matter and dry matter yield of *Sesbania rostrata.*

ced this parameter. Green matter yield increased from 23.35 t/ha (no inoculation) to 23.73 t/ha when inoculated. Phosphorus application at 30 kg/ha gave a higher green matter yield of 15.85 t/ha compared to 15.53 t/ha at no application.

Among the interactions, l_2p_1 (liming at 500 kgs/ha + P_2O_5 at 30 kg/ha) exerted significant influence and produced the highest green matter yield of 18.85 t/ha.

Liming significantly influenced the total dry matter production with 500 kg lime/ha producing 6.05 t/ha and 250 kg lime/ha producing 5.18 t/ha. Inoculation of the seed and stem resulted in a dry matter production of 7.59 t/ha compared to 7.49 t/ha at no inoculation. Phosphorus application significantly influenced this parameter with 30 kg P_2O_5/ha producing 5.08 t/ha compared to 4.98 t/ha at no application.

Among the interactions l_2p_1(lime at 500 kg/ha + phosphorus at 30 kg/ha) produced the maximum value of 6.07 t/ha.

Calcium is one of the major plant nutrients and it influences plant growth characters (Tisdale et al. 1985). The influence of liming in increasing the soil pH as well as improving the availability of nutrients such as P, K, Ca and Mg and thereby increasing the

PLATE V. *Sesbania rostrata* at harvest (50 DAS) in Experiment II

PLATE V

growth attributes is a well known fact which requires no further explanation. The importance of lime application in acid soils particularly for legumes has been stressed by many workers in the field like Lowther (1975), and Manguiat _et al_. (1987b). In fact the success of legume cultivation in acid soils is wholly dependent on application of lime as it has been found absolutely essential for microbial activity. (Jones (1966); Danso (1975); Ramanagowda (1981). The result of the experiment is in confirmity with the findings of the above workers. The increase in green matter yield due to lime application might have led for the increase in dry matter yield.

The influence of inoculation on increasing the biomass production of _Sesbania rostrata_ may be partly due to the influence of stem nodules which contain chlorophyll and hence has the capacity to photosynthesize (DuHoux, 1984).

Phosphorus is essential for increased root growth which in turn helps in the better absorption of nutrients by plants. This leads to better plant growth (Gauch(1957), Ohlrogge (1962) and Tisdale _et al_. (1985)). Increase in biomass observed in the experiment due to phosphorus application can be attributed to the above fact. Phosphorus application increases the nitrogen uptake by plants (Tisdale _et al_., 1985) which in turn directly increase biomass production. Similar result has also been reported by Manguiat *et al*. (1987b).

The photosynthates produced by stem nodules may have resulted in higher biomass production. The positive effect of inoculation on biomass production observed in this experiment has been confirmed by many earlier workers like Daroy *et al*. (1987) and Manguiat *et al*. (1987b) in *Sesbania rostrata*.

The influence of lime and phosphorus application has been discussed in detail in the preceeding paragraphs. The influence of lime and phosphorus application in increasing the photosynthetic efficiency might have resulted in a higher rate and amount of transport of photosynthates. This might have led to better growth as is shown by increased plant height. Calcium plays an important role in the cell division and multiplication in the meristimatic tissues (Tisdale *et al*., 1985), which itself may have led to increasein plant height. The positive influence of calcium and phosphorus on plant height has been reported by many workers like Yost *et al*. (1985), Manguiat *et al*.(1987a,b) and Ramanagowda (1981). The results of this experiment are in confirmity with the findings of the above workers. The additive effects of individual treatments may have resulted in the interactions being significant.

5.2 Nodule characteristics

5.2.1 Number of root nodules

The data on the number of root nodules per plant are illustrated in Table 6. A perusal of the data revealed that increasing rates of lime application from zero level to 500 kg per hectare increased the nodule number from 47.18 to 72.85 per plant. Inoculation too significantly influenced root nodule number with inoculated plants producing 102.99 nodules per plant compared to 84.49 nodules for uninoculated plants. Phosphorus application did not significantly influence the root nodules number. Among the interactions, lime at 500 kg per hectare + inoculation produced the highest number of root nodules per plant (80.49).

The beneficial effect of lime application in increasing the Rhizobium population in acid soils due to increase in pH has been reported by many workers like Loneragan and Dowling (1958); Jones (1966) and Danso(1975). Lime application might have resulted in a higher Rhizobial population and activity due to the favourable soil reaction created and hence the greater number of root nodules per plant, observed in this experiment. This result is in confirmity with the findings of the above mentioned workers.

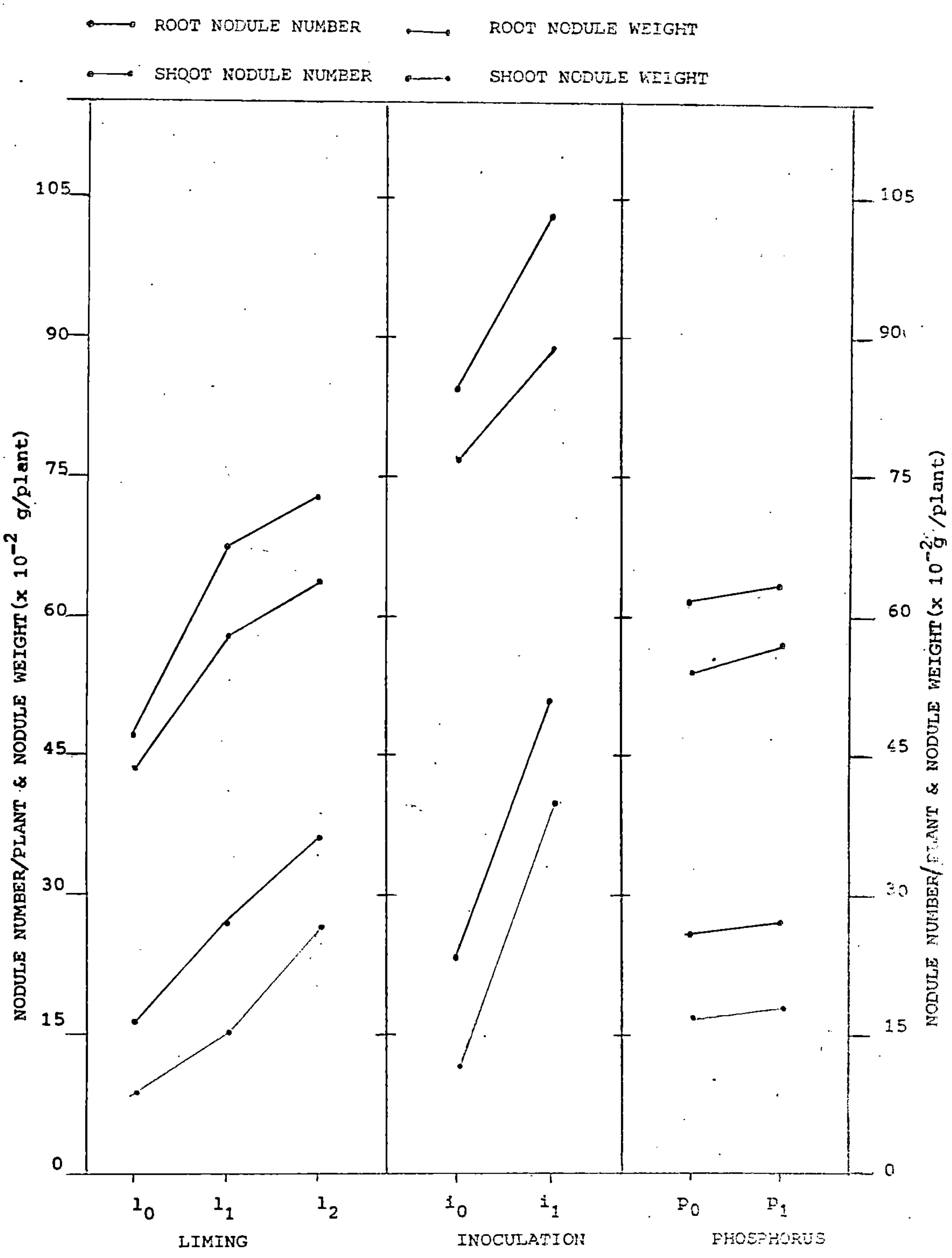

Fig 7 . Effect of liming, rhizobium inoculation and phosphorus application on the nodule characteristics of Sesbania rostrata.

The influence of inoculation on nodule formation is a widely accepted phenomenon. Increase in nodulation due to inoculation of legumes has been reported by workers like Vincent (1958). The results obtained in the present study is in confirmity with the above finding.

5.2.1 Dry weight of root nodules

The data presented in Table 7 showed that liming had exerted significant influence on dry weight of root nodules. Lime application at 500 kg per hectare produced the greatest dry weight (0.643 g/plant) followed by lime application at 250 kg per hectare (0.581 g/plant). Inoculation exerted significant influence on this parameter with inoculated plants showing higher dry weight (0.890 g/plant) compared to uninoculated plants(0.773g/plant). Phosphorus application increased root nodule dry weight with 30 kg P_2O_5/ha giving a nodule dry weight of 0.578 g/plant compared to 0.540 g/plant for no phosphorus application. Among the interaction liming at 500 kg per hectare + inoculation recorded the maximum root nodule dry weight of 0.729 g/plant.

The positive influence of lime application and inoculation in increasing the root nodule number per plant has already been discussed in detail. Increase in root nodule number, observed due to lime application and inoculation might have led to increased weight of root nodules per plant also. Similar findings have been reported by Almeida et al. (1973) and Danso (1975).

Phosphorus application leads to increased nodule number, nodule activity and greater nodule size in many legumes. This fact has been confirmed by workers like deMooy and Pesek (1966) on Soybeans and Luse et al.(1975) on cowpea. In this experiment, phosphorus application increased nodule number even though the increase was not significant. Hence in this experiment increase in dry weight of root nodules may be due to slightly increased nodule number and greater nodule size. The influence of the interaction may be due to the additive effect of the individual treatments.

5.2.2 Number of stem nodules

It can be seen from Table 6 that lime application at 500 kg/ha recorded the maximum number of stem nodules per plant (36.41) followed by lime application at 250 kg/ha (27.12 nodules/plant). Inoculation exerted significant influence on the number of stem nodules per plant with inoculated plants having 56.13 stem nodules/plant compared to 23.84 stem nodules in uninoculated plants. Phosphorus application did not significantly influence the stem nodule number. The interaction lime application at 500 kg/ha + inoculation produced the maximum number of stem nodules per plant (51.78) followed by inoculation + 30 kg p_2O_5/ha producing 38.14 stem nodules/plant.

Sprent et al.(1987) reported that appreciable amounts of calcium must be transported into the plants for proper nodulation. Lowther and Loneragan (1968) showed that increasing calcium concentration inside the legume plants increased the nodule number. Lime application must have resulted in the higher uptake of calcium by the plant and hence higher calcium content. This may have resulted in increased stem nodule number per plant, in this experiment.

Sesbania rostrata is capable of picking up an aerial spray inoculant (Dreyfus et al. 1985) and produce intense stem nodulation. In this experiment, an aerial spray of Rhizobium culture was given at 10 DAS and this might have resulted in higher nodulation on the stem, compared to uninoculated plants, which is in agreement with the view expressed by Dreyfus et al. (1985). The influence of the interactions may be attributed to the additive effects of the individual treatments.

PLATE VI. Stem nodulation in *Sesbania rostrata* due to different treatments.

KEY		
	A	Control
	B	inoculation
	C	Lime at 500 kg/ha + inoculation
	D	phosphorus application
	E	Lime at 250 kg/ha + inoculation

PLATE VII. Root nodules of *Sesbania rostrata* at harvest (50 DAS) in Experiment II.

PLATE VI

PLATE VII

5.2.3 Dry weight of stem nodules

Data presented in Table 7 showed that lime application and inoculation significantly influenced this parameter. Application of lime at 500 kg/ha resulted in maximum dry weight of stem nodules (0.279g/plant) followed by lime application at 250 kg/ha (0.167g/plant). Inoculation of plants showed higher dry weight of stem nodules (0.409g/plant) compared to uninoculated plants (0.122g/plant). Phosphorus application did not significantly influence dry weight of stem nodules per plant. Among the interactions like application at 500 kg per hectare + inoculation gave the maximum value of 0.449g/plant for this parameter.

It has already been discussed in detail the positive effect of lime application and inoculation on increasing the stem nodule number per plant. An increase in stem nodule number by lime application might have probably led to an increase in dry weight of stem nodules also. The positive influence of the interactions may be due to the additive effect of the individual treatments.

5.3. Chemical analysis of plant samples

5.3.1 Nitrogen content of root nodules

From Table 7, it can be seen that nitrogen content of root nodules increased with lime application. Lime application at 500 kg/ha recorded a value of 1.42 per cent whereas lime application at 250 kg/ha recorded 1.41 per cent. Between the two levels, there was no statistically significant difference, but both were superior to no application of lime. Inoculated plants had higher nitrogen content in the root nodules(2.07%) compared with uninoculated plants. Phosphorus application at 30 kg/ha produced a higher nitrogen content in the root nodule (1.33%) as compared with no application (0 kg/ha). All interactions significantly influenced this parameter. Among LI interactions l_2i_1(500 kg lime/ha + inoculation) recorded highest nitrogen percentage of 1.47 in root nodules. Among LP interactions l_2p_1(500 kg lime/ha + 30 kg P_2O_5/ha) recorded maximum value of 1.48% nitrogen in root nodules. Among PI interactions, inoculation + 30 kg P_2O_5/ha recorded the highest percentage of nitrogen in the root nodules (1.41).

The beneficial effects of lime application in nodulation has been discussed in the earlier paragraphs. The higher nodule activity may have resulted in a higher rate of nitrogen fixation by root nodules, and hence observed a higher nitrogen content. An increase in nodule nitrogen content due to inoculation can be attributed to the above explanation.

Workers like deMooy and Pesek (1966) on soybean and Luse <u>et al</u>. (1975) on cowpea have demonstrated the necessity of phosphorus for increasing nodulation and nodule activity. Phosphorus application may have increased the nitrogen fixing capacity of the root nodules resulting in an increased nitrogen content in the root nodules. The influence of various interactions on this parameter may be due to the additive effect of individual treatments.

5.3.2 Nitrogen content of the stem nodules

A perusal of data presented in Table 7 indicates that lime application at 500 kg/ha gave the maximum nitrogen content of 1.45 per cent, in the stem nodules followed by 1.32 per cent for 250 kg lime/ha. Inoculated plants had a higher percentage of nitrogen content in the stem nodules (2.23%) compared with uninoculated plants. Phosphorus application did not significantly influence stem nodules. Lime application at 500 kg/ha + inoculation recorded the maximum nitrogen content of the stem nodules (1.69%).

Lime application may have resulted in a higher uptake of calcium by the plant thus bringing about a higher calcium content. This might have resulted in better nodulation on stem and better nodule activity resulting in higher nitrogen fixation and direct relationships between calcium content of plant and nodule activity has been reported by Lowther and Loneragan (1968) and Sprent _et al_.(1987).

Inoculation (both seed and stem) may have promoted higher nodulation and the formation of more number of effective nodules on the stem might have resulted in better nodule activity and hence higher nitrogen content in stem nodules. Similar conclusions have been reported by Dreyfus _et al_.(1985) and Anon (1988) from TNAU, Coimbatore, on _Sesbania rostrata_. The influence of LI interaction may be due to the additive effect of the individual treatments.

5.3.3 Nitrogen content of plants

Reference to Table 8 shows that application of lime at 500 kg/ha recorded the highest level of nitrogen in plant (2.12%), whereas no application of lime resulted in the lowest nitrogen content of 2.03%. Inoculation had a positive influence on nitrogen content of the plant with inoculated plants having 3.09 per cent nitrogen compared with 3.01 per cent nitrogen for uninoculated plants. Phosphorus application increased nitrogen content of the plant with 30 kg P_2O_5 recording 2.05 per cent nitrogen. Among LI interactions 500 kg lime/ha + inoculation recorded the maximum value of 2.13 per cent.

Among LP interactions 500 kg lime/ha + phosphorus application recorded the highest value of 2.13 per cent, whereas for IP interaction inoculation + 30 kg P_2O_5/ha recorded the highest value of 2.07 per cent.

Application of lime may have resulted in higher uptake of nitrogen, through its favourable effect on soil pH. This may have led to higher nitrogen content of plant due to increasing rate of lime applications. Calcium application also influences the stem nodule activity and nitrogen fixation (as discussed earlier) and this may also have resulted in higher nitrogen content of plant. Similar findings were reported by workers like Rose (1963) and Munns and Fox (1977).

Inoculation may have increased the nitrogen content of the plants due to its influence on the nodule activity (as discussed earlier). Phosphorus application to plants bring about increased root growth (Ohlrogge(1962); Tisdale et al. 1985). This may have resulted in the higher uptake of nitrogen by the plant and hence higher nitrogen content.

5.3.4 Phosphorus content of plant

Data presented in Table 8 reveals that lime application at 500 kg/ha gave the highest phosphorus content of plant (0.67%), followed by lime application at 250 kg/ha. Inoculation did not significantly influence the phosphorus level of the plant. Phosphorus application at 30 kg/ha resulted in a plant phosphorus content of 0.65 per cent compared with 0.57 per cent for no application of phosphorus.

Liming at 500 kg/ha + inoculation recorded the highest phosphorus content of 0.68 per cent among LI interactions, where as lime application at 500 kg/ha + 30 kg P_2O_5/ha recorded the highest phosphorus content of 0.72 per cent.

The effect of lime application on the improvement of the soil pH in acid soil and the availability of phosphorus is well known. Similar increases in plant phosphorus content due to lime application on soybeans has been reported by Robson et al. (1970).

5.3.5 Potassium content of plant

Lime application had a negative effect on the potassium content of plant (Table 8). Lime application at 500 kg/ha recorded the lowest plant potassium content of 1.46 per cent whereas no application of lime resulted in the highest plant potassium content (1.72 per cent). Inoculation had no significant influence on the potassium content of plant. Phosphorus application at 30 kg/ha recorded highest potassium content of 1.69 per cent compared with no application which recorded 1.54 per cent. Among the interactions inoculation + phosphorus and no lime application + 30 kg P_2O_5 recorded the highest potassium contents of 1.77 per cent and 1.83 per cent respectively.

The reduced content of potassium due to lime application may be attributed to the antagonism between potassium and calcium (Black 1967; Russel, 1973). Similar finding has been reported by Santos et al.(1976), in legumes.

The positive effect of phosphorus application may be attributed to its influence on promoting the root growth (Ohlrogge (1962); Gauch, (1957); Tisdale et al. 1985), which in turn may have resulted in higher uptake of potassium and hence higher content of potassium in plant. The additive effect of inoculation and phosphorus might have contributed for the significance of IP interaction.

5.3.6 Calcium content of plant

Data presented in Table 8 shows that lime application significantly influenced the calcium content of plant. Application of lime at 500 kg/ha resulted in the highest calcium content of 1.20 per cent whereas no application resulted in plant calcium content of

0.82 per cent. Inoculated plants showed a higher calcium content (1.57%) compared with 1.50 per cent for uninoculated plants. Phosphorus application increased the calcium content with 1.04 per cent for 30 kg P_2O_5/ha application, and 1.00 per cent for no application. Interaction effects significantly influenced calcium content of plants. Among LP interactions, liming at 500 kg/ha + with or without 30 kg P_2O_5/ha (ie. l_2P_1 and l_2p_0) produced maximum calcium 1.20 per cent in the plant. Among LI interactions, liming at 500 kg/ha + inoculation recorded the maximum value of 1.22 per cent.

Increase in calcium content of plant due to lime application is a common phenomenon. Baumgartner _et al_. (1974) and Singh and Dahiya (1976) also observed increased calcium content in legumes by lime application.

The influence of inoculation and role of calcium in increasing nodule number and nodule activity has been discussed in detail earlier. Formation of more number of stem nodules might have resulted in the higher transport of calcium to the aerial parts and hence the observed higher calcium content in plant parts.

The increased root growth due to phosphorus application might have resulted in a higher uptake of calcium by plants.

5.3.7. Magnesium content of plant

The data reveal the significant influence of lime application on the magnesium content of plant. Magnesium content decreased from 0.29 per cent at 0 kg/ha lime application to 0.22 per cent at 500 kg/ha lime application. But inoculation and phosphorus application did not significantly influence the magnesium content of plants in the present study.

If a particular cation makes up a high proportion of the cations externally its rate of absorption relative to other cations is increased and its competitive ability relative to the other cations for the fairly constant number of internal cation equivalents is increased. The consequence is that the ion in high proportion externally, tends to be in high proportion internally and that the proportion of other cations in the plant is reduced (Black, 1967). Lime was applied in this experiment and hence the concentration of Ca^{2+} in the soil would have been high and this may have resulted in its higher uptake and accumulation in the plant. This may have led to a decrease in the uptake of Mg^{2+} due to competition and hence the lesser concentration of magnesium in the plant. Such a phenomenon has also been reported by workers like Russel (1973) and Fried and Broeschart, (1967).

5.4 Nutrient uptake by plants

Reference to Table 9 indicates the positive effect of like application in increasing the uptake of N,P,K, Ca and Mg by the plants. Increasing lime application from 0 kg/ha to 500 kg/ha enhanced the nitrogen uptake by plants from 80.72 kg/ha to 120.45 kg/ha. Similar increase in lime application increased phosphorus uptake from 19.81 to 40.30 kg/ha, potassium uptake by 56.55 to 106.26 kg/ha, calcium uptake from 31.87 to 72.51 kg/ha and magnesium uptake from 7.49 to 19.11 kg/ha.

Inoculated plants showed significant uptake of N, P, K and Ca when compared with uninoculated plants. But inoculation did not significantly influence the magnesium uptake by plants. Inoculated plants accumulated 156.35 kg/ha nitrogen, 47.30 kg/ha phosphorus, 126.97 kg/ha potassium and 81.36 kg/ha calcium as compared to uninoculated plants which showed an uptake of 149.87 kg N/ha, 45.29 kg P/ha, 122.56 kg K/ha and 77.37 kg Calcium/ha.

Phosphorus application at 30 kg/ha significantly influenced the uptake of nutrients except magnesium. Compared with no phosphorus application, application of phosphorus resulted in an uptake of 103.44 kg nitrogen/ha, 33.43 kg phosphorus/ha, 88.32 potassium/ha and 53.89 kg calcium/ha by plants which were significantly higher than no phosphorus application which recorded an uptake of

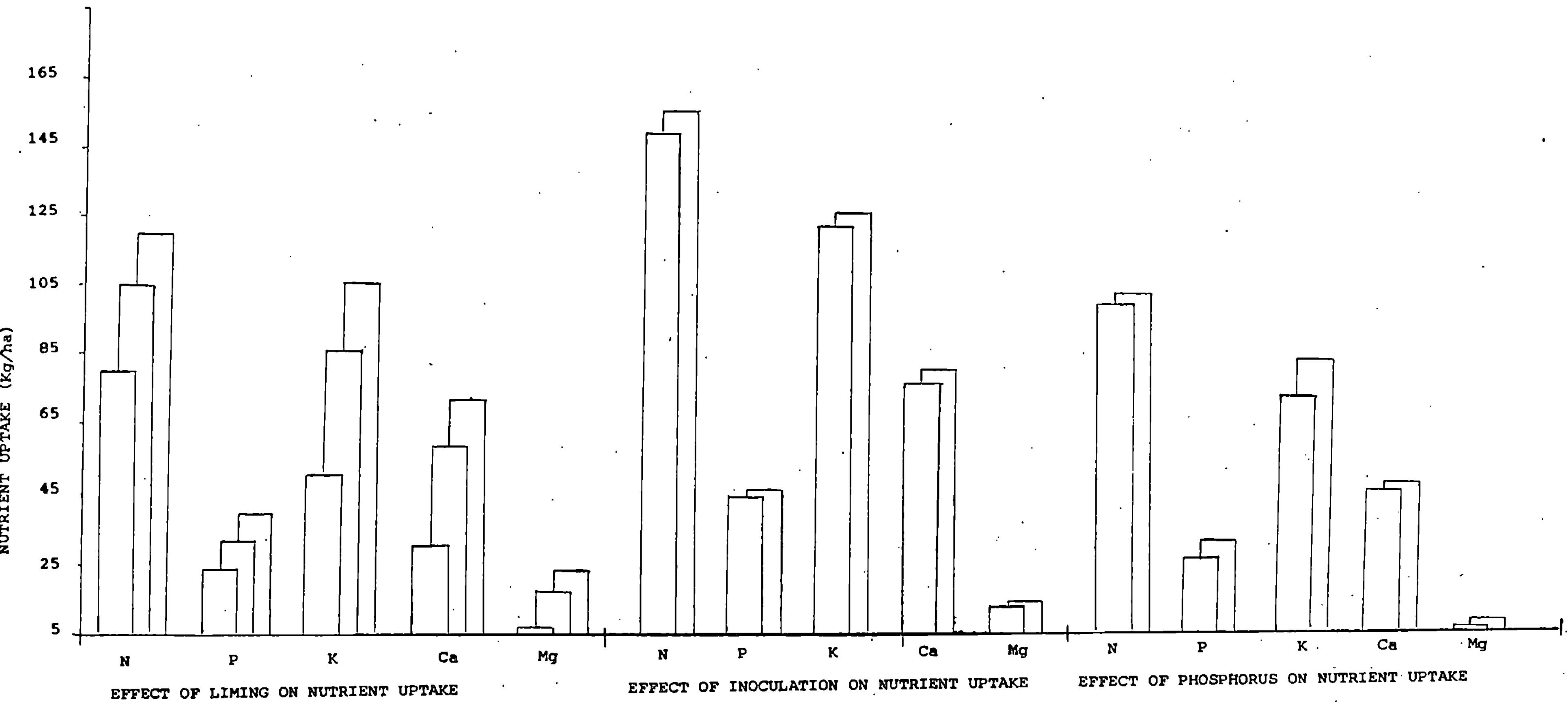

Fig 8 . Effect of liming , rhizobium inoculation and phosphorus application on the nutrient uptake of <u>Sesbania rostrata</u>.

100.70 kg N/ha, 28.30 kg P/ha, 78.04 kg potassium/ha and 51.93 kg calcium/ha respectively.

Nitrogen uptake was significantly influenced by all the interactions. Among LI interactions 500 kg lime + inoculation recorded the maximum value of 123.95 kg/ha among LP interactions, 500 kg lime + 30 kg P_2O_5/ha recorded the highest value of 120.46 kg/ha. Among IP interactions, inoculation + 30 kg P_2O_5/ha recorded highest value of 104.89 kg/ha.

Phosphorus uptake was influenced significantly only by LP interaction wherein liming at 500 kg/ha + 30 kg P_2O_5 recorded the highest uptake value of 43.70 kg/ha.

Potassium uptake was significantly influenced only by LP interaction wherein liming at 500 kg/ha + 30 kg P_2O_5/ha, recorded the highest uptake of 110.55 kg/ha.

Calcium uptake was significantly influenced by both LI and LP interactions. Among LI interaction liming at 500 kg/ha + inoculation registered the highest uptake value of 74 kg/ha, whereas among LP interactions. Liming at 500 kg/ha + 30 kg P_2O_5/ha recorded the highest value of 72.92 kg/ha.

None of the interactions exerted any significant influence on the uptake of magnesium by plants.

The influence of lime application, phosphorus application and inoculation in increasing the green and dry matter production of Sesbania rostrata has been discussed earlier in detail. In general, the uptake of plant nutrients at any stage of growth is mainly related to dry matter production. According to Tanaka et al. (1964), the nutrient uptake is controlled by factors like nutrient availability in soil, nutrient absorption power of roots and rate of increase of dry matter production. Since appreciable increase in dry matter production has been observed in the present study due to lime application, inoculation and phosphorus application, it is quite natural that uptake of nutrients have also shown an upward trend, as observed by Tanaka et al. (1964).

Similar increases in the uptake of nutrients have been reported by workers like Elpete (1972), Manguiat et al. (1987b), Dreyfus et al. (1985) in legumes.

The additive effects of individual treatments may have resulted in significant effect of interaction.

5.5. Soil analysis

5.5.1 Available nitrogen content of the soil

The data on the analysis of available nutrients in soils is given on Table 10. A perusal of the data reveals that lime application at 500 kg/ha recorded the maximum available nitrogen value of 503.50 kg/ha whereas no application resulted in available nitrogen content of 318.70 kg/ha.

Inoculation significantly influenced the nitrogen content of soil. Inoculated plots showed a higher available soil nitrogen (652 kg/ha) compared to 594.95 kg/ha for uninoculated plots.

Phosphorus application at 30 kg/ha recorded the highest value for this parameter, recording 422.83 kg/ha, compared with 408.47 kg/ha for no application. The interactions significantly influenced soil available nitrogen. Among LP interactions lime application at 500 kg/ha + 30 kg P_2O_5/ha recorded the highest value of 511.83 kg/ha. Among LI interactions, lime application at 500 kg/ha + inoculation recorded the maximum value of 528.32 kg/ha. Among IP interactions, inoculation + 30 kg P_2O_5/ha recorded the highest value of 436.11 kg/ha.

The influence of lime on the available nitrogen content of the soil can be attributed to its indirect effect on mineralization (Tisdale et al., 1985). The role of lime application in improving nodulation and nitrogen fixation has already been discussed. This may have led to an increase in the available nitrogen content of the soil. Appreciable increase in available nitrogen content of soil due to legume cultivation has been reported by Tisdale et al. (1985), Ramanagowda (1981), Dobereiner (1975), Rose (1963). Increase in soil available nitrogen content due to inoculation can be attributed to its favourable influence on nodulation and nitrogen fixation by legumes, which has been discussed earlier. The positive influence of phosphorus can also be attributed to the same reasons, mentioned above.

5.5.2 Available phosphorus content of the soil

Lime application significantly influenced the available phosphorus content of the soil (Table 10). Lime application at 500 kg/ha recorded the maximum value of 42.40 kg P_2O_5/ha. Inoculation did not significantly influence the available phosphorus content of the soil. Phosphorus application at 30 kg/ha increased the available phosphorus content to 41.14 kg/ha, from 31.96 kg P_2O_5/ha, at no application. The interaction LP significantly increased the available soil phosphorus content with 500 kg lime/ha + 30 kg P_2O_5/ha recording the highest value of 46.37 kg P_2O_5/ha.

The influence of liming in increasing the soil pH and hence the availability of phosphorus is well known. The increase in the phosphorus status consequent to phosphorus application is an already established fact.

5.5.3 Available potassium, calcium and magnesium content of soil

A perusal of Table 10 reveals that, none of the treatments viz. lime application, phosphorus application inoculation or their interactions influenced the available K status.

Available calcium content of the soil was increased significantly by liming. Lime application at 500 kg/ha produced the maximum available calcium content of 251.75 kg/ha. Phosphorus application and inoculation did not significantly influence the available calcium content of the soil.

Available magnesium content of the soil was not influenced by liming, inoculation or phosphorus application.

Increase in calcium content of soil due to lime application is an already established fact and needs no discussion.

5.6 Soil characteristics

5.6.1 Soil pH

From the data presented in Table 11, it can be seen that soil pH was significantly influenced by lime application. Inoculation and phosphorus application did not influence the soil pH. Interaction effects also did not influence this parameter significantly.

The increase in soil pH due to lime application in an acid soil is an already established fact and does not warrant detailed discussion.

5.6.2 Soil organic carbon

An appraisal of Table 11 reveals that lime application, inoculation or phosphorus application had no significant influence on this parameter. The interactions too did not influence the soil organic carbon after the experiment.

5.6.3 *Rhizobium* population in the rhizosphere

A perusal of data in Table 11 indicates that *Rhizobium* population in rhizosphere was significantly influenced by lime application. Increasing the lime application from 0 kg/ha to 500 kg/ha increased the Rhizobium population from 20.83 x 10^4/g soil to 69.08 x 10^4/g soil. Inoculated plots had a higher *Rhizobium* population of 64.0 x 10^4/g soil, compared to 59.75 x 10^4/g soil for uninoculated plots. Phosphorus application at 30 kg/ha increased the *Rhizobium* population to 44.72 x 10^4/g soil from 37.78 x 10^4/g soil at no P_2O_5 application. Interactions too, significantly influenced the *Rhizobium* population. Among LI interactions, 500 kg lime/ha + inoculation registered the maximum *Rhizobium* population of 69.30 x 10^4/g soil. Among LP interactions lime application at 500 kg/ha + 30 kg P_2O_5/ha, the highest *Rhizobium* population of 76.16 x 10^4/g soil. Among IP interactions, inoculation + 30 kg P_2O_5/ha registered the highest *Rhizobium* population of 49 x 10^4/g soil.

Workers like Wilson (1926) and Loneragan and Dowling (1956) have reported the detrimental effects of low pH on the *Rhizobium* population. Many *Rhizobium* strains are very sensitive to low pH and perish due to soil acidity (Tisdale *et al*. 1985). Higher *Rhizobium* population in limed soils has been reported by Jones (1966), Donso (1975) and Ramanagowda (1981). Similar increase in *Rhizobium* population due to liming has been observed in this experiment also since liming was found to increase the soil pH. The role of phosphorus in inducing nodulation and bringing about higher nodule activity has already been discussed in detail. Nodulation itself leads to the multiplication of *Rhizobia* in the rhizosphere. These two factors may have led to the increased microbial activity and population in the soil. Further the phosphorus application is known to increase *Rhizobium* multiplication in the rhizosphere. At flowering stage of the crop, some of the nodules might have undergone senescence, releasing *Rhizobia* in the rhizosphere. It is also a well known fact that nodulation in legumes is a phenomenon resulting from the multiplication of Rhizobium in the rhizosphere. All the above factors might have led to the increase in Rhizobial count in rhizosphere, due to phosphorus application.

Inoculation itself is a process of introducing the Rhizobium in the soil and hence an increase in Rhizobium population due to inoculation does not need further explanation.

The positive influence of the interaction effects may be due to the additive effects of the individual treatments.

5.6.5 Economics of cultivation

A perusal of the data in Table 12 reveals that all treatments registered significantly higher net profits than the control. As the level of liming increased from zero to 500 kg/ha, the net profit increased from Rs.23.25 to Rs.1050.00. The corresponding increase in cost-benefit ratio was from 0.99 to 1.26. Thus in terms of biomass yield, net returns and cost-benefit ratio, liming at 500 kg/ha turned out to be the best treatment. Inoculation gave a net profit of Rs.3152.75 and a cost benefit ratio of 1.93, compared with no inoculation which gave Rs. 3073.25 and 1.91 respectively for the said parameters. Increases in net returns and cost-benefit ratio due to inoculation turned out to be negligible (Rs.79.50 and 0.02 respectively). Thus under the agro-climatic conditions of Vellayani inoculation may not be necessary to ensure appreciable net returns and higher cost-benefit ratio. Since inoculation has been proved to be highly beneficial to legume crops in general, it is only logical to follow inoculation practice in Sesbania rostrata, as in case of other legumes. Application of phosphorus gave a lowest net profit (Rs.823.25) compared with no application (Rs.922.75). The cost-benefit ratio declined from 1.28 to 1.23 when phosphorus was applied. The marginal increase in gross income (Rs.4358.75 -4270.75 = Rs.88.00) due to increase in biomass by phosphorus application was greatly nullified by the expenditure incurred in the application of the fertilizer. This has resulted in the lowering of net returns and cost-benefit ratio. Thus, under the agro-climatic conditions of Vellayani, it may be concluded that application of phosphorus is not warranted for Sesbania rostrata, when economics of cultivation is taken into consideration.

From the above discussion, it can be concluded that highest level of lime application (500 kg/ha) tried in the experiment together with inoculation has positively influenced the growth parameters, nutrient uptake, soil content of nitrogen and phosphorus and *Rhizobium* population . Net profit and cost-benefit ratio also increased due to liming at 500 kg/ha and inoculation. Though phosphorus application at 30 kg/ha positively influenced the said parameters, its effect was marginal and greatly nullified by the cost of the fertilizer, which resulted in a lower net profit and cost-benefit ratio. Thus, phosphorus application is not absolutely necessary for *Sesbania rostrata* under the agro-climatic conditions of Vellayani.

SUMMARY

SUMMARY

A field investigation was carried out at College of Agriculture, Vellayani to determine the biomass productivity and nutrient accumulation of *Sesbania rostrata*. This investigation was carried out as two separate experiments. Experiment I. The main objective of this experiment was to assess the biomass productivity and nutrient accumulation of *Sesbania rostrata* in relation to other green manures viz. *Sesbania aculeata* and *Crotolaria juncea*. The main objective of Experiment II was to determine the effect of *Rhizobium* inoculation, liming and phosphorus application on the biomass productivity of *Sesbania rostrata*. Both the experiments were carried out in rice fields during the summer season of 1988-89. The soil of the experimental site(s) was sandy clay loam, low in available nitrogen and phosphorus and medium in available potassium. The weather was normal during the period of crop growth. The experiment(s) were laid out in a randomised block design with three replications. The results of the experiment(s) are summarised below.

EXPERIMENT I

1. Plant height, green matter production and dry matter production of green manures increased with delay in

date of harvest upto 50 DAS. Crotolaria juncea recorded the maximum value for the above parameters (108.71 cm, 998 t/ha and 3.40 t/ha respectively). Interaction effect between days of harvest and green manures was also significant, with Crotolaria juncea at 50 DAS, giving 155.37 cm plant height, 14.98 t/ha green matter and 5.36 t/ha dry matter.

2. Time of harvest significantly influenced the nodule characteristics (root nodule number and weight). The three green manures recorded maximum value for these parameters at 50 DAS. Among the green manures, Sesbania aculeata produced the maximum number of root nodules (40.70 per plant) and dry weight (0.209 g/plant). Interaction effect was also significant with Sesbania aculeata at 50 DAS producing maximum root nodule number and dry weight (51.55 and 0.329 g per plant) respectively.

3. Nitrogen content in root nodules recorded the maximum value of 1.20 per cent at 50 DAS. Among the green manures, Sesbania aculeata recorded the maximum nodule nitrogen content of 0.94%. Nitrogen content in plant parts decreased from 2.39 per cent at 30 DAS to 1.97 per cent at 50 DAS. Among the green manures Sesbania aculeata recorded the maximum nitrogen content.

4. Delay in date of harvest resulted in an increase in phosphorus content of the green manures. Maximum phosphorus content of 0.52 per cent was obtained at 50 DAS. Comparison of the green manures revealed that Crotolaria juncea had the highest phosphorus content of 0.46 per cent.

5. Potassium, Calcium and Magnesium content in the green manures recorded with delay in days of harvest. Maximum values of 1.55,0.88 and 0.31 per cent respectively were obtained for the mentioned nutrients at 50 DAS. Among the green manures Sesbania aculeata recorded maximum potassium content of 1.54 per cent. Sesbania rostrata, a maximum value of 0.87 per cent for calcium and Crotolaria juncea a maximum value of 0.39 per cent for magnesium.

6. Nitrogen uptake by the plants was significantly influenced by delay in days of harvest. Harvesting the green manure plants at 50 DAS yielded the maximum nitrogen uptake of 90.13 kg/ha. Among the green manures, Crotolaria juncea yielded maximum nitrogen (70.54 kg/ha). Interaction between green manures and days of harvest also proved to be significant with Crotolaria juncea at 50 DAS producing a nitrogen yield of 103.78 kg/ha.

7. Maximum phosphorus uptake by the green manures was observed at 50 DAS (23.88 kg/ha). Crotolaria juncea proved superior to the other two green manures, by registering phosphorus uptake of 16.79 kg/ha. Crotolaria juncea at 50 DAS registered the highest uptake of phosphorus (30.07 kg/ha).

8. Delay in days of harvest also increased the uptake of potassium, calcium and magnesium. At 50 DAS, the uptake of the mentioned nutrients were 71.37, 40.13 and 14.93 kg/ha respectively. Among the green manures, Sesbania aculeata recorded the highest uptake value for potassium and calcium (48.45 and 27.17 kg/ha respectively), whereas Crotolaria juncea recorded the highest uptake value for magnesium (13.85 kg/ha). Interaction between green manures and days of harvest also proved to be significant. Crotolaria juncea at 50 DAS recorded the highest uptake of potassium and magnesium (78.78 and 23.57 kg/ha respectively) whereas Sesbania aculeata recorded the highest uptake of calcium (43.24 kg/ha).

9. Available nitrogen status of the soil increased from 193.78 kg/ha at 30 DAS to 273.44 kg/ha at 50 DAS. The initial soil level was 170 kg/ha. Neither the green manures nor days of harvest x green manure interaction influenced this parameter.

10. Available phosphorus, potassium, calcium and magnesium status of the soil was not influenced by the days of harvest, type of green manure or their interactions Soil organic carbon after the experiment also followed the same trend.

11. Soil pH was not influenced by delay in days of harvest of the green manures. Soil in which Sesbania aculeata was grown registered a pH of 5.2, compared with a pH of 5.3 for soils in which Sesbania rostrata and Crotolaria juncea were grown.

It can be concluded that the optimum time of harvest of the green manures during the third crop season in rice fallows is at 50 DAS, (flowering stage) since all the parameters investigated in this experiment showed a maximum value at this period. Among the green manures tried Crotolaria juncea proved to be superior, in terms of green matter yield, dry matter yield and nutrient uptake followed by Sesbania aculeata. The performance of Sesbania rostrata was not at all satisfactory under the agro-climatic conditions that existed in Trivandrum district during the summer season. The present study reveals the superiority of Crotolaria juncea as a green manure under Southern Kerala conditions, during the summer season as compared with the other two green manures tried.

EXPERIMENT II

The results of the experiment to determine the effect of liming, Rhizobium inoculation and phosphorus application on Sesbania rostrata are summarised below.

1. Plant height, green matter and dry matter yields were positively influenced by lime application. Liming at 500 kg/ha gave the highest value for the above parameters (168.23 cm, 18.72 t/ha and 6.05 t/ha respectively). Phosphorus application at 30 kg/ha also recorded a maximum value for the said parameters (135.56 cm, 15.85 t/ha and 5.08 t/ha). Interaction did not influence plant height, but it gave the maximum value for green and dry matter yield (23.73 and 7.59 t/ha respectively). Liming at 500 kg per hectare and phosphorus at 30 kg/ha recorded maximum value of 18.85 t/ha and 6.07 t/ha green matter yield and dry matter yield respectively.

2. Lime application at 500 kg/ha produced the maximum number of root nodules (72.85 /plant) and stem nodules (26.41 /plant). Inoculation produced 102.99 root nodules/plant compared with 84.49 for no inoculation. Stem nodule number of 56.13/plant for inoculation and 23.84/plant for no inoculation was also seen.

Phosphorus application did not influence both the root and stem nodule numbers. Among the interactions liming at 500 kg/ha + inoculation gave the maximum value of 80.49 root nodules/plant and 51.78 stem nodules/plant.

3. Lime application significantly influenced the dry weight of root nodules with 500 kg lime/ha producing the maximum root nodule dry weight of 0.643 g/plant. Inoculation produced a higher dry weight of 0.890 g/plant compared with no inoculation. Phosphorus application gave a higher root nodule dry weight (0.378 g/plant). Among the interactions, only lime application at 500 kg/ha + inoculation, influenced this parameter, by recording a maximum value of 0.729g/plant.

4. Lime application at 500 kg/ha produced the maximum stem nodule dry weight (0.279g/plant). Inoculated plants showed higher stem nodule dry weight (0.409g/plant) compared with uninoculated plants. Phosphorus application did not influence this parameter. Lime application at 500 kg/ha + inoculation produced the highest stem nodule dry weight of 0.449g/plant among the interactions.

5. Nitrogen content of root nodules registered highest value at 500 kg/ha (1.42%). But this was on par with 250 kg/ha lime application (1.41%). Inoculation of plants produced a higher root nodule nitrogen (2.07%) compared with control (1.88%). Phosphorus application at 30 kg/ha gave a

higher root nodule content of 1.33 per cent compared with no application (1.30%). Lime application at 500 kg/ha + inoculation gave the highest root nodule nitrogen content of 1.47 per cent. Among LP interactions, lime application at 500 kg/ha + 30 kg P_2O_5/ha recorded the highest root nodule nitrogen content of 1.48 per cent. Inoculation + 30 kg phosphorus/ha recorded the maximum root nodule nitrogen content of 1.41 per cent among LI interactions.

6. Lime application at 500 kg/ha produced the maximum nitrogen content in the stem nodules (1.45%). Inoculation resulted in a stem nodule nitrogen content of 2.23 per cent compared with 1.83 per cent for no inoculation. Phosphorus application did not significantly affect stem nodule nitrogen. Lime application at 500 kg/ha + inoculation recorded the maximum nitrogen content of the stem nodules (1.69%).

7. Increasing lime levels increased the nitrogen content of plant, with 500 kg/ha lime recording a maximum nitrogen content of 2.12 per cent. Inoculated plants showed a higher nitrogen content (3.09%) compared with 3.01 per cent for uninoculated plants. Phosphorus

application increased nitrogen content of plant with 30 kg P_2O_5 recording 2.05%. Among LI interactions 500 kg lime/ha + inoculation recorded the maximum value of 2.13%. Similarly lime application of 500 kg/ha + phosphorus application gave the highest value of 2.13%, whereas for IP interaction, inoculation + 30 kg P_2O_5/ha recorded the highest value of 2.07% nitrogen.

8. Highest level of lime application (500 kg/ha) gave the highest plant phosphorus content of 0.67% . Inoculation did not significantly influence the phosphorus level of the plant. Phosphorus application at 30 kg/ha resulted in a plant phosphorus content of 0.65% compared with 0.57% for no application. Liming at 500 kg/ha + inoculation recorded the highest phosphorus content of 0.68% among LI interactions whereas lime application at 500 kg/ha + 30 kg P_2O_5/ha recorded the highest phosphorus content of 0.72%

9. Maximum potassium content of 1.72% in plant was obtained in treatment where no lime was applied. Increasing levels of lime decreased the potassium

content of plant. Inoculation had no significant influence on the potassium content of plant. Phosphorus application at 30 kg/ha recorded highest potassium content of 1.69%. Among the interactions, inoculation + phosphorus and no lime application + phosphorus treated the highest potassium contents of 1.77% and 1.83% respectively.

10. Increasing levels of lime application increased calcium content of plant with 500 kg lime/ha recording the highest value of 1.20%. Inoculated plants showed a higher calcium content of 1.57% compared with 1.50% for uninoculated plants. Phosphorus application increased the calcium content with 30 kg P_2O_5/ha giving a calcium content of 1.04% in the plant. Among LP interactions, liming at 500 kg/ha + with or without phosphorus produced maximum content of 1.20% in the plant. Liming at 500 kg/ha + inoculation recorded the maximum value of 1.22% among LI interactions.

11. Magnesium content of plant decreased from 0.29% to 0.22% when liming was increased from zero level to 500 kg/ha. Inoculation and phosphorus application did not significantly influence this parameter.

12. Nitrogen uptake was the highest at 500 kg lime/ha application (120.44 kg/ha). Inoculated plants showed a higher nitrogen uptake of 156.35 kg/ha compared with 149.87 kg N/ha for no inoculation. Phosphorus application gave a higher nitrogen uptake of 103.44 kg/ha. Among LI interactions, 500 kg lime/ha + inoculation registered the highest nitrogen uptake value of 123.95 kg/ha. Liming at 500 kg/ha + phosphorus registered highest nitrogen uptake value among LP interactions (120.46 kg/ha). Among IP interactions, inoculation + phosphorus application gave the highest value for this parameter (104.88 kg/ha).

13. Phosphorus uptake of plants was maximum (40.30 kg/ha) when lime application was at 500 kg/ha. Inoculated plant accumulated 47.30 kg/ha phosphorus. Phosphorus application resulted in an uptake of 33.43 kg/ha compared with 28.30 kg/ha for no application. Among LP interactions 500 kg lime/ha + phosphorus application at 30 kg/ha resulted in the highest uptake of 43.70 kg/ha.

14. Highest potassium uptake of 106.26 kg/ha was obtained at the highest level of lime application. Inoculation and phosphorus application significantly influenced this parameter by registering highest values of 126.97 and 88.32 kg/ha respectively. Only LP interaction influenced this parameter with 500 kg lime/ha + phosphorus application registering the highest uptake value of 110.55 kg/ha.

15. Application of 500 kg lime/ha produced the highest uptake of calcium (72.51 kg/ha). Inoculation and phosphorus application significantly influenced this parameter by registering highest values of 81.36 and 53.89 kg/ha respectively. Among LI interactions, liming at 500 kg/ha + inoculation produced the highest uptake value of 74 kg/ha. Lime application at 500 kg/ha + phosphorus application proved to be the best among LP interactions by giving the highest uptake value of 72.92 kg/ha.

16. Magnesium uptake of plants was influenced only by lime application, with the highest level of liming (500 kg/ha) producing the highest uptake of 19.11 kg/ha.

17. Lime application at 500 kg/ha gave the highest value for the available nitrogen status of the soil after the experiment (503.50 kg/ ha) compared with 318.70 kg/ha for no application of lime. Inoculated plots had higher available nitrogen in soil (652 kg/ha) when compared with uninoculated plots (594.95 kg/ha). Phosphorus application enriched available nitrogen in soil (422.83 kg/ha) compared with 408.47 kg/ha for no application. Lime application at 500 kg/ha + inoculation proved to be the best among LI interactions by registering highest value of 528.33 kg/ha. Among LP interactions, lime application at 500 kg/ha + phosphorus application gave maximum nitrogen enrichment of soil (511.83 kg/ha) whereas inoculation + phosphorus application proved to be the best among IP interactions by giving the highest value of 436.11 kg/ha available nitrogen.

18. Highest level of lime application (500 kg/ha) gave the maximum value for available phosphorus in soil after the experiment 42.40 kg/ha). Inoculation did not significantly influence this parameter. Phosphorus application at 30 kg/ha increased the

available phosphorus content to 41.14 kg/ha from 31.96 kg/ha at no application. The interaction LP significantly increased the available soil phosphorus content with 500 kg lime/ha + 30 kg phosphorus recording the highest value of 46.37 kg/ha.

19. None of the treatments viz. lime application, phosphorus application or inoculation nor their interactions influenced the available potassium and magnesium status of the soil after the experiment. Available calcium content of the soil was significantly increased by liming with the highest level of liming (500 kg/ha) producing the maximum available calcium content of 251.75 kg/ha.

20. Soil organic carbon status after the experiment was not influenced by any of the treatments or their interactions.

21. Soil pH after the experiment was influenced only by lime application, with the highest level of liming (500 kg/ha) giving the highest pH value of 5.9 compared with 5.2 for no application.

22. Lime application at 500 kg/ha produced the maximum *Rhizobium* population of 69.08 x 10^4/g soil. Inoculation and phosphorus application significantly influenced this parameter, by giving highest values of 64 x 10^4/g soil and 44.72 x 10^4/g soil respectively. Lime application at 500 kg/ha + inoculation gave the highest value of 69.30 x 10^4/g soil, among LI interactions. Among LP and IP interactions, liming at 500 kg/ha + phosphorus application and inoculation + phosphorus application gave the highest values for *Rhizobium* population (76.16 x 10^4/g and 49 x 10^4/g soil respectively).

23. Highest level of lime application (500 kg/ha) registered maximum net profit and cost-benefit ratio (Rs.1050.00 and 1.26 respectively). Inoculation too followed the same trend by giving highest value for net returns and cost-benefit ratio (Rs.3152.75 and 1.93), even though this increase was only marginal compared with no inoculation. Phosphorus application recorded lower net returns and cost-benefit ratio compared with no application(Rs.823.25 and 1.23 compared with 922.75 and 1.28 for no application).

It can be concluded that highest level of lime application (500 kg/ha) tried in the experiment together with inoculation has positively influenced the growth parameters, nutrient uptake, soil content of nitrogen, phosphorus and calcium and Rhizobium population. Net profit and cost benefit ratio also showed higher values for the said treatments. Though phosphorus application at 30 kg/ha positively influenced the said parameters, its effect was marginal and greatly nullified by the cost of fertilizer, which resulted in a lower net profit and cost-benefit ratio. Thus it seems that phosphorus application is not absolutely necessary for the growth of Sesbania rostrata under the agro-climatic conditions of Trivandrum district.

Future line of work

In Kerala, agronomic investigations on Sesbania rostrata are meagre. This study is to determine the biomass productivity and nutrient accumulation in this plant under our conditions. There is much scope for a detailed investigation on the potentiality of this plant in our State. Major emphasis may be given to the suggestions listed below for future line of work, on this green manure.

(i) In this investigation, lime application was found to produce a linear effect on the growth parameters and nitrogen yield of *Sesbania rostrata*. Hence higher levels of liming may be tried to determine the optimum level of lime for the best performance.

(ii) *Sesbania rostrata* is a semi-aquatic plant. It gives better growth and nitrogen yield under flooded conditions than under non-flooded conditions. Hence investigations on this line may be undertaken during June-July season (onset of South-west monsoon) in the lowlands (rice fields) to assess its performance under water logged conditions.

(iii) Experiments may be conducted to assess the growth performance and nitrogen fixation of this green manure, when it is planted as an alley crop along with lowland rice.

(iv) Incorporation of *Sesbania rostrata* into soil and its residual effect on the growth, yield and quality characters of the succeeding crop of rice may be studied. In this regard comparisons can be made by including other green manures also.

(v) Investigations may be carried out to determine the effect of <u>Sesbania rostrata</u> as a green manure on the physico-chemical properties of soil.

(vi) Crop rotation studies by including <u>Sesbania rostrata</u> in the rotation.

REFERENCE

REFERENCES

*Almeida, D.L. De, Pessanha, G.G. and Penteado, A.De.F. (1973). Effect of liming and phosphorus and nitrogen fertilizer on nodulation and yields of beans. Pesqui Agropecu. Bras. 8(7): 127-130.

Alonso, C.S. (1934). A test of some green manure crops. Philipp. Agric. 23: 543-558.

Anonymous (1983). IITA Research Highlights. pp.26-28.

Anonymous (1985). Annual report. IRRI. pp.402-406.

Anonymous (1986). Annual report. IRRI. pp.342-346.

Anonymous (1988). Evaluation of Sesbania rostrata for green manuring. Agronomy Department, Annual Report, CSCMS, TNAU. pp. 9-11.

Batra, L. (1985). Ameliorative effect of green manuring with dhaincha on soils of two sodicity levels and its residual effect on subsequent sorghum crop. Indian J. Agri.Sci. 55(1): 32-34.

*Baumgartner, J.G., Lopes, E.S., De mette, J.D., Miyasaka, S., Igue, T. and Guimarees, G. (1974). Effect of liming and mineral fertilizer on the yield of Soybean var. Santa Maria on lowland soil. Bragantia. 33: 1-10.

Beri, V., Meelu, O.P. and Khind, C.S. (1989). Biomass production, nitrogen accumulation, sumbiotic effectiveness and minerlization of green manures in relation to yield of wetland rice. Trop. Agric. 66(1):11-16.

Bharadwaj, K.K.R. and Dev, S.P. (1985). Production and decomposition of Sesbania cannabina (Retz) Pers in relation to its effect on the yield of wet land rice. Trop. Agric. 62(3): 233-236.

Bindumadhava Rao, R.S. and Venkatesan, G. (1965). A few observations on the growing of Sesbania speciosa (for green manure) at Aduthurai (India). Madras Agric. J. 52(6):280-283.

Black, C.A. (1967). Soil plant relationships. I Wiley Eastern reprint in 1973. pp.230-238.

Bouyoucos, C.J. (1962). Hydrometer method improved for making particle size analysis of soil. Agron. J. 54:464-465.

*Bronson, K.F.(1983). The effect of flooding on the nitrogen contibutions of a grass and two legume green manures to transplanted lowland rice. M.S. Thesis, University of Philippines at Los Banos, Laguna.

Chapman, A.L. and Myers, R.J.K. (1987). Nitrogen contributed by grain to rice grown in relation to the Cunumurra soils of the Ord irrigated area, Western Australia. Aust. J. Exp. Agric. 27(1): 155-163.

Cochran, W.G. and Cox. G.M. (1965). Experimental designs John Wiley and Sons Inc., New York.

Dalal, R.C. and Quilt, P. (1977). Effect of nitrogen, phosphorus, liming and molybdenum on nodulation and grain yield of pigeon pea. Agron. J. 69(5): 854-857.

Danso, S.K.A. (1975). The ecology of Rhizobium and recent advances in the study of the ecology of Rhizobium. In: Ayanabe, A. and Dart, P.J. (eds). Biological Nitrogen in the Farming Systems of the Tropics. John Wiley and Sons, New York. pp.115-126.

deMooy, C.J. and Pesek, J. (1966). Nodulation responses of Soybeans to added phosphorus, potassium and calcium soils. Agron. J. 58: 225-280.

Dobereiner, J. (1975). Present and future opportunities to improve nitrogen nutrition of crops through biological fixation. In: Ayanabe, A. and Dart, P.J. (eds). Biological Nitrogen Fixation in the Farming Systems of the Tropics. John Wiley and Sons, New York. pp.3-12.

*Dobereiner, J., Arruda, N.B.de (1967). Inter-relation between varieties and nutrition in nodulation and symbiosis of soybean (Glycine max (L) Merril) Pesq. Agropec. Bras. 2: 475-487.

Daroy, L.G., Shahajahan Miyan, M., Furoc, R.E. and Ladha, J.K. (1987). Preliminary report on the responses of Sesbania rostrata to inoculation under flooded and unflooded conditions. Abstract of FCSSP papers. The Philipp. J.Crop Sci. 11(Supplt.1) 526.

Dreyfus, B. Rinaudo, G. and Dommergues, Y. (1985). Observations on the use of Sesbania rostrata as green manure in paddy fields. MIRCEN J. of Appl. Microbiol. and Biotech. 1(2):111-122.

DuHoux, E. (1984). Ontogenese des nodules culinaires de Sesbania rostrata. Can.J.Bot. 62: 982-994.

Eaglesham, A.R.J. and Szalay, A.A. (1983). Aerial stem nodules on Aeschynomene sp. Plant Sci. letters. 29: 265-272.

Elpete, D.M. (1972). Assessment of lime requirements of Eastern Nigerian soils. Soil Sci. 113(5): 363-375.

Evans, D.O. and Rotar, P.P. (1987). Productivity of Sesbania species. Trop. Agric. 64(3):193-200.

Fried, M. and Broeshart, H. (1967). The Soil-Plant System in relation to inorganic nutrition. Academic Press New York, pp 98-105.

Furoc, R.E., Dizon, M.A., Meelu, O.P., Morris, R.A. and Marques, E.P. (1985). Effect of flooding regimes and planting dates to N accumulation of tree Sesbania species and consequently to transplanted rice. Abstract of FCSSP papers. Philipp. J. Crop Sci. 10(Suppl.1), S 18.

Gauch, H.G. (1957). Mineral nutrition of plants. Annu. Rev. Plant Physiol 8: 31.

Ghai, S.K., Rao, D.L.N. and Batra, L. (1984). More rice through dhaincha. Intensive Agriculture. 22(5): 21-22.

Ghai, S.K., Rao, D.L.N. and Batra, L. (1988). Nitrogen contribution to wetland rice by green manuring with Sesbania spp in an alkaline soil. Biol. Fertil. Soils 6: 22-25.

Gines, H.C., Furoc, R.E., Meelu, O.P., Dizon, M.A. and Morris, R.A. (1987). Studies on green manuring of rice in farmers' fields. Abstract of FCSSP papers. Philipp. J. Crop Sci. 11 (Suppl 1) iD-4P.

Hati, N. (1987). Effect of combing chemical N and Sesbania aculeata in upland rice. IRRN 12(2): 44-45.

*Hernandez, C.C. and Coloma, B.B. (1957). The value of legumes as green manure. J. Soil Sci. Soc. Philipp. 9:104-106.

*Hernandez, C.C., Villanueva, I.E. and Magtang, M.V. (1957). The value of legumes as green manure. J. Soil Sci. Soc. Philipp. 9: 52-58.

Hundal, H.S., Biswas, C.R. and Vig.A.C. (1988). Phosphorus sorption characteristics of flooded soil amended with green manures. Trop.Agric. 65(2):185-187.

Jackson, M.L. (1973). Soil Chemical Analysis. 2nd edn. Prentice Hall of India (Pvt) Ltd., New Delhi. pp.1-498.

Jakobsen, I. (1985). The role of phosphorus in nitrogen fixation by young pea plants (Pisum sativum). Physiolgia plantarum. 64(2):190-196.

Jones, G.D. (1966). The contribution of white clover to a mixed upland sword. II. Factors affecting the density and effectiveness of Rhizobium trifolii. Pl. Soil. 24: 250-259.

Joseph, P.A. (1986). Dhaincha as an organic source of nutrients for rice. Agric. Res. J. Kerala 24(1): 80-82.

Khind, C.S., Meelu, O.P. and Beri, V. (1983). Age of dhaincha, green matter and nitrogen economy in rice. IRRN 8(2): 17.

Ladha, J.K., Watanabe, I. and Saono, S. (1987). Nitrogen fixation by leguminous green manures and practices for its enhancement in tropical lowland rice. In proceedings on the International Symposium on Sustainable Agriculture- the role of green manure crops in rice farming systems held at IRRI from 25-29 May, 1987. pp. 1-41.

Loneragan, J.P. and Dowling, E.J. (1958). The interaction of calcium and hydrogen ions in the nodulation of subterranean clover. Aust. J.Agric. Res. 9: 464-472.

Lowther, W.L. (1975). Interaction of lime and seed pelleting on the nodulation and growth of white clover. 2. oversown trials. New Zealand. J. Agric. Res. 18(4): 357-360.

Lowther, W.L. and Loneragan, J.P. (1968). Calcium and nodulation in subterranean clover (Trifolium subterraneum, L.) Pl. Physiol. 43: 1362-1366.

Luse, R.L., Kang, B.T., Fox, R.L. and Nangju, D. (1975). Protein quality in grain legumes grown in the lowland humid tropics with special reference to West Africa. In Fertilizer Use and Production XIth Colloquium International Potash Institute, Bornhalm, Denmark.

Manguiat, I.J., Guinto, D.P., Sebiano, A.G. and Jalalon, A.T. (1987a). Influence of rhizobial inoculation, phosphorus fertilization, and liming on the nodulation, nitrogen fixation and biomass production of Sesbania rostrata grown in an acidic soil. Abstract of FCSSP papers. Philipp. J. Crop. Sci. 12:525.

Manguiat, I.J., Sebiano, A.G., Jalalon, A.T. and Guinto, D.P. (1987b). Biofertilization and nitrogen fixation potentials of Sesbania rostrata under flooded and non-flooded conditions as affected by inoculation and nitrogen fixation. Abstract of FCSSP papers. Philipp. J. Crop.Sci. 12: S 25.

*Mattos, P.L., DeSouza, P., Das, L., Calidas, R.C. and Dantas, J.L.L. (1980). Utilization of the free space between double rows of cassava by Crotolaria juncea. Communicado Technico CNP Mandioca e Fruticultura: 7:7.

Meelu, O.P., Furoc, R.E., Dizon, M.A., Morris, R.A. and Marquezes, E.P. (1985b). Evaluation of different green manures on rice yield and soil fertility. Philipp. J. Crop Sci. 10(Suppl.1) S 3.

Meelu, O.P., Furoc, R.E., Dizon, M.A., Morris, R.A. and Marquezes, E.P. (1986). Studies on the integrated management of fertilizer nitrogen and organic manures in cropping sequence. 1. Evaluation of green manures. Abstract of FCSSP papers. Philipp. J. Crop. Sci. 11(Suppl 1) 2D-2a.

Meelu, O.P., Torres, O.P. and Morris, R.A. (1985a). Effect of integrated nitrogen management on crop yields and soil fertility in five rice based cropping sequences. Philipp. J. Crop Sci. 10(Suppl.1) S 3.

Mello, F. and De, A.F. (1978). (Nitrogen fixation by some legumes) Fixacao de nitrogenio por algumas leguminosas. Revista de Agricultura. Piracicaba, Brazil 53 (1/2): 59-64.

Morris, R.A., Furoc, R.E. and Dizon, M.A. (1987). Rice responses to a short duration green manure. II N recovery and utilization. Agron. J. 78: 413-416.

Mulongoy, K. (1986). Potential of Sesbania rostrata (Biem) as nitrogen source in alley cropping systems. Biol. Agric. Hort. 3(4): 341-346.

Munns, D.N. and Fox, R.L. (1977). Comparative lime requirement of tropical and temperate legumes. Pl. Soil. 46(3): 353-348.

Nair, K.S., Khan, A. and Ramaswamy, P.P. (1970). Effect of seed inoculation with Rhizobium on yield and N content of green manure crops. Madras Agric. J. 57(4): 213-216.

Nicol, W.E. and Turner, R.C. (1957). The pH of non-calcareous near neutral soils. Can. J. Soil Sci. 37: 96-101.

Ohlrogge, A.J. (1962). Some-soil-root-plant relationship. Soil Sci. 93:30.

*Osseni, B., Godefroy, J. and Rinaudo, G. (1987). Behaviour of Sesbania rostrata in Southern Ivory coast. Fruits (France) 42(3):131-139.

Perkin-Elmer Corporation (1982). Analytical Methods for Atomic Absorption Spectrophotometry. AY-5 pp. 1-3. Perkin-Elmer Corporation, Norwalk, Connecticut, USA.

Poonia, S.R., Jhorar, L.R. (1974). Effect of different concentrations and ratios of Ca and Na in the growth medium on the yield and chemical composition of dhaincha and wheat. Indian J. Agric. Sci. 44 (12): 871-874.

Rajbhandari, N.K. (1984). The effect of age of two leguminous green manure crop on transplanted rice yield M.S Thesis University of Philippines, at Los Banos, Laguna.

Ramanagowda, P. (1981). Production potential of fodder cowpea varieties in coconut garden at different levels of nitrogen and lime. Ph.D. Thesis submitted to Kerala Agricultural University.

Rinaudo, G., Dreyfus, B. and Dommergues, Y. (1982a). Sesbania rostrata as a green manure for rice in West Africa. In. Graham, P.H. and Haris, S.C. (eds). Biological nitrogen fixation technology for tropical agriculture. CIAT, Cali, Colombia, pp. 441-445.

Rinaudo, G., Dreyfus, B. and Dommergues, Y. (1983). Sesbania rostrata green manure and the nitrogen content of rice crop and soil. Soil Biol. Biochem. 15: 111-113.

Robson, A.D., Thomas, A.L. and Loneragan, J.F. (1970). Nodulation and growth of Medicago truncatula on acid soils. I. Effect of $CaCO_3$ and inoculation level on nodulation of Medicago truncatula on moderately acid soil. Aust. J. Agric. Res. 21: 427-434.

Rose, H.L. (1963). Comparative studies on the fixation of nitrogen by certain common legumes. M.Sc(Ag.) Thesis submitted to the University of Kerala.

Russel, E.W. (1973). Soil conditions and plant growth. 10th Edition. Longman Group Ltd. London, pp.327-387.

Saint Macary, H., Marqueses, E.P., Torres, R.O. and Morris, R.A. (1985). Effect of flooding on growth and nitrogen fixation of two Sesbania species. Philipp. J.Crop. Sci. 10: 17-20.

Santos, J., Das, Q. and Cabral, F.M.M. (1976). Effect of lime and fertilizer on growth of berseem. Herb. Abst. 49(1): 13 No.4.

Sarkar, A.K. (1976). Effect of N, P, K fertilizers and lime on yield of crops grown in lateritic uplands. Indian Agriculturist. 20(3):169-175.

* Schmidt Lepardeur, M.A. and Lassavilly, F. (1986). Plants as factories for nitrogen production. Inter Tropiques (France) 18: 18-21.

Sharma, R.C., Govindakrishnan, P.M. and Singh, R.P. (1988). Effects of different green manures and fodder crops on cropy yields and P needs of potato-wheat systems in the north western plains of India. Exp. Agric. 24(1):97-103.

Sharma, S.K. and Murty, K.K. (1988). Green manure crop performance in semi arid region of India. IRRLN 13(3): 23-24.

Sidhu, A.S., Aggarwal, G.C. and Singh, N.T. (1985). Pattern of nitrogen fixation in green manure crops. J. of Res. Punjab Agricultural University 22 (4):647-649.

Singh, M. and Dahiya, S.S. (1976). Effect of $CaCO_3$ and Iron on the availability and uptake of Fe,Mn, P and Ca in pea. Plant. Sci. 44(3):511-520.

Singh, N.T., Sidhu, A.S. and Aggarwal, G.C. (1985). Nodulation pattern in green manure crops. J. of Res. Punjab Agricultural University. 22(3):585-588

Singh, R., Singh, B.P., Kumar, B and Chand, D. (1988). Sesbania rostrata: A promising source of Bio-fertilizer. Seeds and Farms. 14(4):9-10.

Singh, Y., Singh, B., Maskina, M.S. and Meelu, O.P. (1988). Effect of organic manures, crop residues and green manure (Sesbania aculeata) on nitrogen and phosphorus transformation in a sandy loam at field capacity and under waterlogged conditions. Biol. Fertil. Soils. 6: 183-187.

Snyder, G.H., Kretschmer, A.E. and Sartain, J.B. (1978). Field response of fodder tropical legumes to lime and super phosphate. Agron. J. 70(2): 269-272.

Sprent, J.I., Giannakis, C. and Wallace, W. (1987). Transport of nitrate and calcium into legume root nodules. J. Experimental Bot. 38(192):1121-1128.

Sreerama Reddy, B.A. (1977). Influence of soil phosphorus and lime status on yield and composition of a legume and a millet. Thesis. University of Agrl. Sciences, Bangalore. From Mysore J. Agric. Sci. 12: 515.

Subbiah, B.V. and Asija, C.L. (1956). A rapid procedure for the estimation of available nitrogen in soils. Current Sci. 25(8): 259-260.

*Tanaka, A., Havasero, S.A., Garcia, C.V., Parao, G.T. and Romirez, E. (1964). Growth habit of the rice plant in the tropics and its effect on nitrogen response. Int. Rice Res. Inst. Teck. Bull. 3: 1-80.

Terchune, E.C. (1977). Prospects for increasing food production through efficient energy utilization. In: Lockeretz, W (Ed) Agriculture and Energy. Acad.Press. Inc., New York. pp.625-637.

Tisdale, S.L., Nelson, W.L. and Beaton, J.D. (1985). Soil Fertility and Fertilizers.(4th Ed). Mac Millan Publishing Co. Inc., New York. pp.1-733.

*Tripathi, S.K. and Edward, J.C. (1978). Nitrogen enriching capacity of inoculated and uninoculated kharif and rabi season legumes. Allahabad Farmer 49(1): 43-46.

Vachhani, M.V. and Murty, K.S. (1964). Green manuring for rice. Bull. 4. Central Rice Res. Inst. Cuttack. India. p.26

Ventura, W., Mascarina, G.B., Furoc, R.E. and Watanabe, I. (1987). Azolla and Sesbania as Biofertilizers for lowland rice. Philipp. J. Crop.Sci. 12(2): 61-69.

Vincent, J.M. (1958). Survival of the root-nodule bacteria. In: Hallsworth, E.G. (Ed) Nutrition of legumes. Butterworths, London. pp.108-123.

Vincent, J.M. (1970). A Manual for the practical study of of Root-Nodule Bacteria. IBP Handbook No.15, 125-126. Blackwell Scientific Publications. Oxford.

Vincent, J.M. and Waters, L.M. (1954). The root nodule bacteria as factors in clover establishment in the red basaltic soils of the Lismore district. New South Wales II. Survival and success of inoculation in laboratory trials. Aust. J. Agric. Res. 5: 61-76.

Visperas, R.M., Furoc, R., Morris, R.A., Vergara, B.S. and Patena, G. (1987). Flowering response of Sesbania rostrata to photoperiod. Philipp. J. Crop. Sci. 12(3):147-149.

Wilson, J.K. (1926). Legume bacteria population of the soil. J.Am.Soc. Agron. 18: 911-919.

*Yamada, M., Haraki, T., Watanabe, Y., Somepoulpon, R., Sasiprapa, V. and Nardsomboas, C. (1986). Multiple cropping on paddy field. Tech. Bull. Tropical Agriculture Research Centre, Japan. 20:168-185.

* Yates, F. (1937). The Design and Analysis of Factorial Experiments. Tech. Comm. 35. Imperial Bureau of Soil Science, Harpenden.

*Yin, Y.X. and Lu, W.J. (1987). A study on formation and nitrogen fixation activity on the stem nodules of *Sesbania rostrata*. Journal of Nanjing Agricultural University. 2: 63-68.

Yost, R.S., Evans, D.O. and Saidy, N.A. (1985). Tropical legumes for N production, growth and N content in relation to soil pH. Trop.Agric. 62: 20-24.

* Originals not seen.

APPENDICES

APPENDIX I

Weather data during the Cropping period (12 December 1988 to February 1,1989)

Standard week	Period		Rain fall (mm)	Maximum tempera-ture (^oC)	Minimum tempera-ture (^oC)	Relative humidity (%)
	From	To				
50	Dec.8	Dec.14	00	22.24	77.42	70.85
51	Dec.15	Dec.21	00	32.05	22.18	73.35
52	Dec.22	Dec.28	00	32.61	21.78	67.42
01	Dec.29	Jan.4	00	33.00	21.13	64.64
02	Jan.05	Jan.11	00	31.49	21.18	69.57
03	Jan.12	Jan.18	00	31.62	21.66	73.14
04	Jan.19	Jan.25	00	31.56	21.95	73.71
05	Jan.26	Feb.01	00	31.40	22.42	77.36
06	Feb.02	Feb.08	00	30.84	18.60	76.00

Source: Meteorological observatory, College of Agriculture, Vellayani.

APPENDIX II

Weather conditions at Vellayani (Average of 15 years, 1974 - 1988)

Standard week	Period		Rainfall (mm)	Maximum temperature (°C)	Minimum temperature (°C)	Relative humidity (%)
	From	To				
50	Dec.8	Dec.14	00	32.30	23.25	71.32
51	Dec.15	Dec.21	00	32.00	23.17	72.14
52	Dec.22	Dec.28	00	31.65	22.78	71.30
01	Dec.29	Jan.04	00	30.72	22.17	74.51
02	Jan.05	Jan.11	1.2	31.00	21.72	73.64
03	Jan.12	Jan.18	00	32.00	22.62	71.37
04	Jan.19	Jan.25	00	32.00	21.00	73.75
05	Jan.26	Feb.01	1.3	31.50	21.24	76.35
06	Feb.02	Feb.08	1.2	31.12	20.27	77.83

Source: Meteorological Observatory, College of Agriculture, Vellayani.

BIOMASS PRODUCTIVITY AND NUTRIENT ACCUMULATION IN *Sesbania rostrata* INOCULATED WITH *Rhizobium*

BY

MURALI S.

ABSTRACT OF A THESIS
submitted in partial fulfilment of the
requirement for the Degree of
MASTER OF SCIENCE IN AGRICULTURE
Faculty of Agriculture
Kerala Agricultural University

Department of Agronomy
COLLEGE OF AGRICULTURE
VELLAYANI, TRIVANDRUM

1989

ABSTRACT

With a view to study the biomass productivity and nutrient accumulation of *Sesbania rostrata*, a field experiment was initiated at College of Agriculture, Vellayani during summer of 1988-'89. The investigation was carried out as two separate experiments. The objective of Experiment I was to assess the biomass productivity and nutrient accumulation of *Sesbania rostrata* in relation to other green manures, viz. *Sesbania aculeata* and *Crotolaria juncea*. The second experiment was intended to determine the effect of *Rhizobium* inoculation, liming and phosphorus application on the biomass productivity of *Sesbania rostrata*. The experiment(s) were laid out in randomised block design with three replications. The soil of the experimental site(s) was sandy clay loam, low in available nitrogen and phosphorus and medium in available potassium. An abstract of the results is given below.

Optimum time of harvest of the green manures during the third crop season in rice fallows was at flowering stage(50 DAS), since all the parameters investigated showed a maximum value at this period. Among the green manures tried, *Crotolaria juncea* proved to be superior in terms of green matter yield, dry matter yield and

nutrient uptake followed by Sesbania aculeata. At final harvest (50 DAS) Crotolaria juncea plant yielded 14.98 t/ha of biomass, 5.36 t/ha of dry matter and yielded 103.78 kg/ha, nitrogen. The performance of Sesbania rostrata was not at all satisfactory under the agro-climatic conditions of Trivandrum during the summer season. The present study indicated the superiority of Crotolaria juncea as a green manure under Trivandrum conditions during the summer, as compared with the other two green manures tried.

Highest level of lime application (500 kg/ha) tried in the experiment together with inoculation positively influenced the growth parameters, nutrient uptake, soil content of nitrogen, phosphorus, calcium and Rhizobium population. Net returns and cost-benefit ratio also showed higher values for the said treatments. Though phosphorus application at 30 kg/ha positively influenced the said parameters, its effect was negligible and greatly nullified by the cost of fertilizer which resulted in a lower net profit and cost-benefit ratio. Thus, it is revealed from the present study that phosphorus application is not absolutely necessary for growth of Sesbania rostrata under the agro-climatic conditions of Trivandrum district.